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PALAEOECOLOGY OF FOSSIL MAMMAL ASSEMBLAGES FROM SOME AUSTRALIAN CAVES

By N. A. WAKEFIELD*

ABSTRACT: The paper presents an analysis of a subfossil deposit from Pyramids Cave, eastern Victoria, and a reassessment of the Broom fauna of Wombeyan Caves, New South Wales. To provide a basis for the analysis, assessment is made of the habitat of each of 30 species of murids and small marsupials which have been recorded, living or fossil, from within 100 miles of the site. Details are given of the form of the cave, the disposition of the bone deposit found in it, and of the local geology, topography and vegetational formations. Data are presented of numbers and percentages of each mammal species (a) in each of two fractions of the deposit (identified as Holocene and late Pleistocene in age), and (b) in each of several categories of the Pleistocene fraction.

Inferences are drawn regarding changes in vegetation during the period of accumulation of the deposit, and the sequence is related to climatic change during the past 20,000 years. Comparisons are made between cranial measurements of mammal series from the two fractions of the deposit and further, with modern museum series. Data are given of fossil specimens from the Broom deposit, Wombeyan Caves, New South Wales, novelties described from that collection are examined, several lectotypes are nominated, and synonymies with extant species are indicated. The Broom deposit is compared with the Pyramids Cave deposit and an assessment made of the age of the Broom fossil fauna.

INTRODUCTION

Initially the interest in this study centred round the discovery, near Buchan in eastern Victoria, in what is now known as the Pyramids Cave, of a deposit of mammal bones containing specimens of *Burramys*, which was known otherwise only from fossil bone breccia from Wombeyan Caves in eastern New South Wales.

In discussing the Wombeyan Caves fossil fauna, Ride (1960) noted that insufficient was known of modern ecological relationships and of basic taxonomy of Australian mammals for valid comparisons of faunal assemblages and palaeo-ecological interpretations to be made. The research reported here has endeavoured to provide some of the necessary foundation for such work in south-eastern Australia, and has therefore included field studies of habitat and distribution of mammals, taxonomic revision, and quantitative analyses of fossil deposits from various localities.

In previous reports (Wakefield 1960a, 1960b) the Pyramids deposit was shown to consist essentially of pellet material regurgitated by owls of the genus *Tyto*, probably *T. novae-hollandiae*. Two groups of bones were recognized: one hard whitish

(unaltered) bones, the other bones which had become fragile in texture and reddish in colour. These two groups are referred to respectively as the whitish fraction and the reddish fraction of the deposit, and they are eventually identified as Holocene and Pleistocene in age. The term 'modern' is applied to the period of occupancy of Australia by Europeans.

Species names in this paper are according to the taxonomy adopted by Ride (1970), but the family Phalangercidae is here used in the earlier broad sense to include such genera as *Petaurus* and *Burramys*.

Locality and rainfall data are set out in Table 4. Locations of bone deposits are shown in Fig. 1.

Institutions are abbreviated thus: AM (Australian Museum, Sydney); BM (British Museum, Natural History, London); FWD (Fisheries and Wildlife Department, Melbourne); NMV (National Museum of Victoria, Melbourne); SAM (South Australian Museum, Adelaide).

HABITAT DATA OF MARSUPIALS AND MURIDS

This section deals with all native murids and

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ASSESSMENT: Dry sclerophyll forest, including areas near wet forest. M.A.R., 30-65 in.

Antechinus stuartii

Habitat is discussed by Wakefield and Warneke (1967). (FWD, DY8-9; Pyramids area, in wet vegetation.)

ASSESSMENT: Abundant in wet sclerophyll forest, less so in dry forest. M.A.R., 20-75 in.

Antechinus swainsonii

Habitat is discussed by Wakefield and Warneke (1963). (FWD, D509; W Tree, 7 miles N. of Pyramids, in wet tussocky gully.)

ASSESSMENT: Predominantly wet sclerophyll forest, but also wet microhabitats in dry forest areas. M.A.R., 35-95 in.

Phascogale tapoatafa

Marlow (1958): Rainforest, sclerophyll forest, woodland.

SPECIMENS: Brit Brit (C2475, C3135), Casterton (C2655), Cavendish (C4262), Marysville (C6878), Healesville (C1443).

DISCUSSION: Most specimens are from woodland and dry forest areas. Several are from areas of mixed wet and dry sclerophyll forest. No evidence is available of occurrence in wet sclerophyll forest. (C7887; Gelantipy, 23 miles N. of Pyramids, in dry sclerophyll forest.)

ASSESSMENT: Woodland and dry sclerophyll forest, including areas near wet forest. M.A.R., 20-50 in.

Dasyurus viverrinus

Marlow (1958): Uncommon in sclerophyll forest, rare in woodland.

SPECIMENS: Kew (C6058-80), Bacchus Marsh (C6081).

DISCUSSION: According to Troughton (1941) the species was decimated by an epidemic disease in 1901-3 and disappeared over a great part of its known range. No museum specimen is available from eastern Victoria or southern New South Wales. However, Wakefield (1954) states that it was abundant in the Bairnsdale area (eastern Victoria) prior to its disappearance about 1902, and Buckland (1954) records a similar history for the Delegate area (southern New South Wales). The species had lairs in the Pyramids area (Wakefield 1960a, 1960b).

ASSESSMENT: Dry sclerophyll forest and woodland, favouring more open areas and broken rocky country. M.A.R., 20-35 in.

PERAMELIDAE

Perameles nasuta

Marlow (1958): Abundant in rainforest, common in sclerophyll forest, uncommon in woodland.

SPECIMENS: Narracan (C7012-3, C7055, C7190, C7203), Gellibrand River (C7494, C7770), Tolmie Ranges (C7209-11).

DISCUSSION: The Victorian range is mainly in and about wet forests of the central and eastern highlands, south-eastern Victoria and the Otway Ranges, with some dry forest records from eastern Victoria. (C2129-31; Head of Basin Creek, 6 miles NE. of Pyramids, in wet forest; and diggings seen in Pyramids area are attributed to the species.)

ASSESSMENT: Mainly wet sclerophyll forest but also in comparatively wet parts of dry sclerophyll forest. M.A.R., 30-75 in.

Isodon obesulus

Marlow's (1958) classification of habitat is based mainly on (a) specimens from eastern New South Wales now identified in AM collections as *I. macrourus* and (b) specimens from Murray-Darling Junction area regarded by Wakefield (1966) as distinct from the *I. obesulus* of southern Victoria.

SPECIMENS: Portland (C697-9, C714-5), Halls Gap (C7529), Yellingbo (C7056).

DISCUSSION: The Victorian range is mainly near-coastal, in areas with soft soil and dense shrubbery or tussocks. The southern Victorian form is not recorded from Pleistocene deposits and may have crossed from Tasmania during the last glacial period. (FWD, B98; 12 miles W. of Orbost, 21 miles S. of Pyramids, in dry sclerophyll forest.)

ASSESSMENT: Dry sclerophyll forest and heathland, including areas near wet forest. M.A.R., 30-40 in.

PHALANGERIDAE

Acrobates pygmaeus

Marlow (1958): Sclerophyll forest and woodland.

SPECIMENS: Mount Dandenong (C783-4, C3993-4), near Bendock (FWD, F222), Gorae Forest (C5068-70), Ouyen (C4013), Nangiloc (C5937).

DISCUSSION: The Victorian range is from the northern Mallee to southern and eastern Victoria. Most records are from high rainfall areas. No evidence is available of the species inhabiting open woodland. (C1436; W Tree, 7 miles N. of Pyramids, in dry sclerophyll forest.)

ASSESSMENT: Predominantly wet sclerophyll forest and dry forest areas of medium to high rainfall, less common in drier formations. M.A.R., 10-75 in.

Cercartetus nanus

Distribution and habitat are discussed by Wakefield (1963a). (FWD, P230, Nowa Nowa, 19 miles SSW. of Pyramids, in dry forest.)

ASSESSMENT: Dry sclerophyll forest, especially in scrubby near-coastal formations; uncommon in mountain areas of high rainfall. M.A.R., 20-50 in.

Cercartetus lepidus

The species is known on the Australian mainland only from Pleistocene fossils. The few habitat data of the extant Tasmanian population are discussed by Wakefield (1963a). A specimen (SAM, M6338) is reported

from Kangaroo Island, S. Aust. (Aitken 1967), but it is doubtful that the species is indigenous there (Wakefield 1970a).

ASSESSMENT: Probably associated on mainland Australia with wet sclerophyll forest areas.

Burramys parvus

Dixon (1971) discusses the habitat of a specimen collected near Falls Creek, Bogong High Plains, Victoria.

SPECIMENS: Mt. Hotham (C7290), Falls Creek area (C10112).

DISCUSSION: All specimens to date are from about 5,000 to 6,000 ft elevation, in localities subject to heavy winter snow drifts. (Mt. Hotham is 60 miles NW. of Pyramids.)

ASSESSMENT: High montane shrubbery and scattered *Eucalyptus pauciflora*. Mean annual precipitation, 50-95 in.

Gynobelideus leadbeateri

SPECIMENS: Bass River (C4280), 6 miles E. of Marysville (C6193), Tanjil Bren (FWD, P638).

DISCUSSION: All records of unquestionable locality data are from high rainfall areas carrying *Eucalyptus regnans*, *E. nitens* or *E. delegatensis*. (C4377; Sunny-side, 50 miles NW. of Pyramids, in wet forest.)

ASSESSMENT: Wet sclerophyll forest. M.A.R., 40-75 in.

Petaurus breviceps

Marlow (1958): Common in sclerophyll forest, uncommon in woodland.

SPECIMENS: Kallista (C2863), Ferny Creek (C3699), Victoria Valley Road, Grampians (C3006-7).

DISCUSSION: Recorded near Kaniva (Wakefield 1966). There is no specific evidence that the species inhabits open woodland, and it apparently requires close formations approaching sclerophyll forest. (Observed by spotlight near Pyramids, in dry sclerophyll forest.)

ASSESSMENT: Abundant in wet sclerophyll forest, less so in dry forest, occasionally in comparatively close woodland. M.A.R., 20-75 in.

Petaurus norfolcensis

Marlow (1958): Uncommon in sclerophyll forest, rare in woodland.

SPECIMENS: Near Colbinabbin (FWD, P203), Dads-wells Bridge (FWD, P506, P703), Warrenbayne (FWD, P660, P685), between Shepparton and Moor-opna (FWD, P635).

DISCUSSION: Except for an old specimen of doubtful origin (NMV, 'Western Port'), all modern Victorian specimens are from open woodland formations with *Eucalyptus microcarpa* dominant. (Marlow cites a specimen from Bega, N.S.W., 110 miles NE. of Pyramids.)

ASSESSMENT: Woodland. M.A.R., 20-35 in.

Petaurus australis

Habitat is discussed by Wakefield (1970b). (Evidence of feeding observed near Pyramids, in dry sclerophyll forest.)

ASSESSMENT: Wet sclerophyll forest (but not in *Eucalyptus regnans* stands), and dry sclerophyll forest, including riparian corridors in woodlands. M.A.R., 20-97 in.

Pseudocheirus peregrinus

Marlow (1958): Common in rainforests, sclerophyll forests and woodland.

SPECIMENS: Near Warburton (C3903-12), Cashmore (C1495-501).

DISCUSSION: These two series are from wet and dry forest areas respectively. Many concentrations have been noted in wet forests. The species is plentiful in open woodland near Dads-wells Bridge. (Observed by spotlight near Pyramids, in dry sclerophyll forest.)

ASSESSMENT: Abundant in both wet and dry sclerophyll forest, plentiful in some woodlands. M.A.R., 20-75 in.

Schoinobates volans

Marlow (1958): Abundant in sclerophyll forest, uncommon in woodland.

SPECIMENS: Healesville (FWD, P259, P636), 6 miles E. of Marysville (C7242).

DISCUSSION: Victorian distribution is limited to tall forests of central and eastern mountain areas, where population is dense. No specific evidence is available of occurrences in typical dry sclerophyll forest or woodland. (C2132, C2136-8; Head of Basin Creek, 6 miles NE. of Pyramids, in wet forest.)

ASSESSMENT: Abundant in wet sclerophyll forest, less abundant in wetter parts of dry sclerophyll forest. M.A.R., 40-70 in.

MACROPODIDAE

Bettongia gaimardi

Distribution of the now-extinct mainland Australian race is discussed by Wakefield (1967a), but no precise data of Victorian habitat are available. Remains occurred in an owl pellet deposit in the Victoria Range, western Victoria (Wakefield 1963b). For eastern Victoria there is no record as a living modern animal or as prey of owls, but remains of recent age were found in dens of *Dasyurus* in the Pyramids area (Wakefield 1960a).

Potorous tridactylus

Marlow (1958): Rare in rainforest, sclerophyll forest and woodland.

SPECIMEN: 'Muddy Creek ranges' (C6973).

DISCUSSION: It is probable that C6973 originated about Toolangi, near the upper Yea River, of which Muddy Creek is a synonym. (The collector, F. J. Williams, secured other specimens from neighbouring localities in the same region.) (FWD, MT1878; Yalmy River, 18 miles ENE. of Pyramids, at 2,000 ft elevation.)

ASSESSMENT: Wet sclerophyll forest. M.A.R., 40-50 in.

Potorous apicalis

SPECIMENS: Heathmere (FWD, MT531, MT533, MT638-9), Forrest (FWD, MT1201, MT1204-5, MT1207), Pomonal (FWD, MT1241-2, MT1964-5), French Island (FWD, MT1883, MT1887-99).

DISCUSSION: Victorian distribution is lowland and mainly near-coastal, and dense ground cover is required. (FWD, MT1884; Bete Bolong, 19 miles SSE. of Pyramids, in dry sclerophyll forest.)

ASSESSMENT: Scrubs in areas of wet and dry sclerophyll forests. M.A.R., 30-45 in.

MURIDAE

Hydromys chrysogaster

DISCUSSION: Ubiquitous in lakes and estuaries and in streams to moderate elevations. (Reported in Murindal River, 4 miles N. of Pyramids (J. Hodge, pers. comm.).)

ASSESSMENT: In and about waterways irrespective of vegetational formation and rainfall.

Rattus fuscipes assimilis

Calaby (1966): 'Common in rainforest, wet well-vegetated gullies, and along creeks with shrubby vegetation on the banks. It was not found in other situations.'

SPECIMENS: Very large series from Beech Forest (NMV) and Loch Valley (FWD), smaller series from numerous other localities in central and eastern Victoria.

DISCUSSION: Densest populations occur in areas of highest rainfall, in lowland wet sclerophyll forests and in grass and scrub along montane streams. Populations are proportionately less dense in less wet areas. There is no evidence of occurrences in lowland grassland or woodland. (FWD, R1222-3; near Pyramids, in dense vegetation on wet terrain.)

ASSESSMENT: Most abundant in wet sclerophyll forest, less so in comparatively wet situations in dry forest areas. M.A.R., 30-95 in.

Rattus lutreolus

Calaby (1966): 'In long grass along creek banks . . . also in areas of undisturbed long grass in wet hollows in woodlands on higher ground, including wet shelves on hillsides.'

SPECIMENS: Hordern Vale (C392-6, C398-401, C403-17), Portland (C4899, C5490), Grampians (C7343), Stoneyford (C7716, C7766-7).

DISCUSSION: Mainly near-coastal and sometimes sympatric with *R. fuscipes*, but appears to be the less vigorous and does not extend far into the other's habitats. It extends into the basalt plains and Grampians of western Victoria, where *R. fuscipes* is absent. (Observed near Orbost, 22 miles SE. of Pyramids, on deeply grassed alluvial flats.)

ASSESSMENT: On more-or-less flat, well grassed, wet terrain in lowland areas of wet and dry sclerophyll forest, woodland and grassland. M.A.R., 25-55 in.

Pseudomys oralis

The sole living specimen was obtained from Hastings River, north-eastern New South Wales, and no habitat data are recorded.

Pseudomys higginsii

Green (1968): From near sea level to about 3,000 ft, in or near rainforests. M.A.R., about 50-100 in.

DISCUSSION: This assessment applies to the extant Tasmanian race, and it may not be applicable to the extinct mainland Australian race, which is known only from Pleistocene fossils.

ASSESSMENT: The Australian *P. higginsii* probably favoured wet forest areas, but precise habitat is unknown.

Pseudomys fumeus

Brazenor (1934): 'Forest country with thick undergrowth of scrub which is literally riddled with runs of *Rattus assimilis*.'

SPECIMENS: Near Beech Forest (C197, M853), Silverband Falls (FWD, R2430-1, R2438-9), Upper Thomson River (FWD, 5837).

DISCUSSION: The Silverband Falls occurrence is in a wet sclerophyll forest microhabitat in a dry forest region. Only a few relict populations are known, and the species may have had a less restricted range of habitat formerly. (Upper Thomson River is 110 miles W. of Pyramids.)

ASSESSMENT: Wet sclerophyll forest, including microhabitats in comparatively dry areas. M.A.R., 35-75 in. Possibly tolerant of lower rainfall.

Pseudomys novaehollandiae

Keith and Calaby (1968) summarize the habitat of a relict colony in north-eastern New South Wales as lowland dry sclerophyll forest with shrubby and bracken but little grass; M.A.R., 25-53 in.

SPECIMENS: Tyabb (C9578-9; FWD, 5098, 5126-7); Seacombe, 22 miles SSW. of Bairnsdale (C10346-10).

DISCUSSION: The three known relict populations are near-coastal. In the cooler Victorian latitudes a M.A.R. limit somewhat below 53 in. may be assumed. Some early Australian specimens which reached the BM under the name *P. novaehollandiae* prove to be *Mus musculus* (J. A. Mahoney, pers. comm.), so the habitat data of Troughton (1941) may contain error. (Seacombe is 65 miles SW. of Pyramids.)

ASSESSMENT: Dry sclerophyll forest. M.A.R. 25-45 in.

Melomys cervinipes

J. H. Calaby (letter, 3 July 1970) states that the species is found in 'rainforest but also in medium-wet sclerophyll forest' in south-eastern Queensland, and that the type locality, Stradbroke Island, does not carry rainforest.

DISCUSSION: The late Pleistocene subfossils from Pyramids Cave comprise the sole southern Australian record of the species (Mahoney 1965).

ASSESSMENT: Rainforest and wet sclerophyll forest, but evidently with wider tolerance.

Mastacomys fuscus

Green (1968) found that the Tasmanian *M. fuscus* is invariably 'within the vicinity of the drainage systems' of 'wet sedgeland which occur as forest openings'. Calaby and Wimbush (1964) summarize data of distribution and habitat of the Australian mainland populations.

DISCUSSION: With the exception of a predator-killed specimen (C8146) picked up near Leongatha, modern mainland specimens are all from high rainfall areas. However, these represent relict populations, and the species may have occurred formerly in areas of lower rainfall. There is no evidence of occurrence in dense forest, and Green's findings appear to be applicable to Australia also, except that dense growths of grass (*Poa*) may provide cover instead of sedges. (FWD, R3116; Dargo River headwaters, Mt. St. Bernard, 60 miles NW. of Pyramids, by runnel bordered by *Carex* in wet forest area.)

ASSESSMENT: Very wet open areas with low dense vegetational cover, in areas of wet sclerophyll forest, but probably also tolerant of wet terrain with grass/sedge coverage in other vegetational formations. M.A.R., 35-95 in.

Conilurus albipes

Troughton (1941): 'Widely inland wherever there was tree-growth.'

DISCUSSION: The sole modern Victorian record is an observation in the Broadford area in 1839, recorded by Parris (1950).

ASSESSMENT: Woodland. M.A.R., 20-35 in.

None of the three murids—*Pseudomys fumeus*, *P. oralis* and *Conilurus albipes*—has been recorded as a living animal within 100 miles of the Pyramids. The first survives as scattered relict populations (see p. 5) and the other two are presumably extinct. However, subfossil remains indicate that these three, and *Mastacomys fuscus* as well, were each plentiful in the Buchan (and Pyramids) district until very recently, probably until about 100 years ago. The widespread disappearance of populations of these and other pseudomyine murids in SE. Australia, evidently soon after European settlement, suggests an epidemic of the kind thought to have decimated *Dasyurus viverrinus*.

Of the 30 species dealt with in this section, only the two largest, *Bettongia gaimardi* and *Potorous tridactylus*, were not found in the Pyramids Cave deposit. With the addition of 10 species of bat (see Table 1) to the 18 marsupials and 10 murids, the total number of mammals caught by the Pyramids owls stands at 38 species.

PYRAMIDS CAVE**ENVIRONMENT**

Pyramids Cave is approximately 500 ft above

sea level, in the lower part of a north-south cliff some 45 ft high, and half way down the steep easterly slope of a hill capped by the residuals known as the Pyramids, 4 miles NNE. of Buchan, eastern Victoria. The hill is part of the Buchan Caves Limestone formation, of Middle Devonian age (Teichert and Talent 1958), but this gives place, about 200 ft down from the cave, to an extensive tract of acid rock of the Snowy River Volcanics, into which, at the foot of the Pyramids hill, the Murrindal River has cut a minor gorge.

The cave has an open outer chamber, approximately 7 ft long, 7 ft high, and from 1 to 3 ft wide, with its outer lower lip 12 ft above the base of the cliff. Inward from the lip, the floor slopes downward, and about one-third of the deposit of bones was collected from this outer chamber. A ledge against the south wall of the chamber served as a landing platform and pathway, and a slightly higher ledge at the rear provided a roost, for the owls that sheltered in the chamber. (Pl. 1.)

At the base of the rear of the outer chamber, a small opening led to an inner chamber, and during excavation a second, larger, aperture was revealed, underneath the first. The inner chamber comprised a trough 7 ft long and averaging 1 ft wide, filled to a depth of 2 ft with the bulk of the bone deposit, and then a vertical chimney 12 ft deep and several feet in diameter. The trough lay between the two apertures and the upper part of the chimney. From the lower end of the chimney, a horizontal tunnel, about 1 ft wide, 2 ft high, and 10 ft long, led out to the base of the cliff.

The features described comprise the complete cave system, and there is no aperture or crevice anywhere to provide possible connection to any further chamber or tunnel. It is obvious, from the form of the cave system, that, except for the few mammals which may have used the cave as a home, and died there, the deposit was a predator-ordered accumulation which originated in the outer chamber. Gravitational movement, possibly assisted at times by passage of animals to and fro in the cave, would have been responsible for the entry of material into the inner chamber. Possums (*Trichosurus*) had a nest in a recess near the roof of the inner chamber, and residents of this kind may sometimes have maintained their access by scraping back, into the inner chamber, material accumulated in the outer chamber.

The remarkable state of preservation of the deposit, as clean, free bones, appears to have been due to (a) the eastern aspect of the cliff and a considerable overhang above the cave, which protected the system from prevailing westerly weather, (b) the movement of accumulated

material further back into the system, (c) the desiccating action of the limestone dust with which the bones were mixed, and (d) the evident complete absence of water flow into or through the deposit at any stage.

The following material, which did not originate there as prey of owls, was also in the deposit:

A. Cranial and post-cranial bones of a single *Trichosurus*, not specifically identified, which evidently died in the cave.

B. A mummified adult and the remains of several juvenile specimens of *Antechinus stuartii*, which also appear to have died in the cave.

C. A single I_3 , but no other recognizable bones, of *Sarcophilus lanianus*.

D. A quantity of small fragments of large mammal limb-bones.

E. Two incisors and a molar, comparable with those of *Petrogale penicillata*.

Items C, D and E are of the reddish colour of the older fraction of the deposit, and they indicate that the outer chamber was at some stage used as a den of *Sarcophilus*. The macropodid teeth and fragments of limb-bones would represent defaecated remains of this carnivore's food. (See Pl. 1, fig. 3.) Douglas, Kendrick and Merrilces (1966) identify similar fragments, from a cave deposit in Western Australia, as faecal residue of *Sarcophilus*. The entry of this predator into the outer chamber of the Pyramids Cave would require the talus to have been ten feet higher than at present, and that usage would have pre-dated occupancy by owls.

The acid rock formation from the Murrindal River eastward carries dry sclerophyll forest, with *Eucalyptus macrorhyncha*, *E. globoidea*, *E. sideroxylon* and *E. polyanthemus* the main trees. Smaller trees and shrubs include *Acacia melanoxylon*, *A. mearnsii* and *A. botrycephala*. Along Shaws Creek (a tributary of the river) in the same area, there is a minor element of wet sclerophyll forest vegetation, with shrubs such as *Pomaderris aspera*, *Olearia phlogopappa*, *O. argophylla*, *Lomatia myricoides* and *Correa lawrenciana*. In places along the Murrindal River there are minor elements of warm-temperate rainforest vegetation, with the tree *Tristania laurina* and lianas such as *Tylophora barbata*, *Enstrephus latifolius* and *Smilax australis*.

The limestone areas about the cave and the Pyramids hill are open woodland dominated by *Eucalyptus melliodora*, with *Casuarina stricta*, *Acacia implexa* and *Brachychiton populneus*. About the cliffs and steep rocky slopes, *Pittosporum undulatum* and the liana *Marsdenia rostrata*

are abundant, these being typical units of warm-temperate rainforest. There are small rocky ravines in the top of the Pyramids hill, with abundant ferns and other soft-leaved vegetation.

Before it was cleared and extensively grazed, the Buchan limestone area would have comprised an extensive grassy woodland, more or less shrubby on the steeper rocky slopes, wet and deeply grassed in the hollows, and swampy on the alluvial flats.

Mean annual rainfall at the Pyramids would probably be slightly more than at Buchan, and it is therefore estimated at 33 in.

ANALYSIS OF THE DEPOSIT

During the excavation, record was kept of the level and area from which each bag of material was obtained. When it became apparent that the two texture/colour fractions represented two different faunal assemblages which had been separated in time (see below), and that each bag contained a mixture of bones of each fraction, it was concluded that the deposit had been mechanically mixed. It was therefore necessary to abandon the consideration of stratification as the primary factor in the analysis.

THE TWO FRACTIONS OF THE DEPOSIT

It had been suggested (Wakefield 1960b) that the reddish fraction of the deposit was older than the whitish fraction, and subsequent observations tended to confirm this. The basic evidence is as follows:

1. Except for the case of one incomplete skull of *Burramys* (picked out of some material before it was sieved) all cranial material in the reddish fraction comprised single bones dissociated from each other, whereas in the whitish fraction there were many cranial specimens comprising a number of individual bones firmly joined at the sutures.

2. Although both fractions of the deposit evidently originated as material regurgitated by owls in the form of pellets, no bones of the reddish fraction were found in pellets. By contrast, many partial and complete owl pellets were found containing bones of the whitish fraction.

3. Whereas the species represented in the whitish fraction comprised the local modern small mammal fauna, the reddish fraction contained some species not recorded, living or in any other fossil deposit, within several hundred miles of the Pyramids site. (See Table 1 and p. 8.)

4. Though the whole deposit had been accumulated in the one place, bones of the reddish fraction had undergone considerable change in

texture and colour while those of the whitish fraction had not.

Items 3 and 4 are further discussed on p. 9.

The sorting of the deposit into the two fractions was completed, and from each fraction bones were segregated as follows: (a) all cranial, dentary and dental material, (b) a selection of specimens of major post-cranial bones, and (c) a bulk of fragments for radiocarbon dating.

Cranial material and dentaries were identified at species level. As the dentary was almost invariably the most numerous recognizable bone of a species, dentaries were counted to provide data of species numbers in each fraction. Usually, to assess the minimum number for a species, right and left dentaries were counted separately and the greater figure accepted, but for very large groups a total dentary count was halved.

The number for each species and family in (a) the reddish fraction, and (b) the whitish fraction, are shown in Table 1, together with percentage which each species number represents of its fraction.

With the exception of the two wet forest species, *Schoinobates volans* and *Potorous tridactylus*, all small marsupials of which there are modern records from within 25 miles of the Pyramids are represented in the whitish fraction of the deposit. Of the two additional species in the fraction, *Gymnobelideus leadbeateri* was probably present during a phase of local conditions somewhat wetter than those of modern times, but *Petaurus norfolcensis* would have been present until the natural woodlands of *Eucalyptus melliodora* were cleared.

Of the murids, the two species of *Rattus* still occur within the 25-mile radius, and, before intensive grazing was established, the complex of woodland, stony hillslopes and wet grassy depressions of the limestone formation would have provided suitable habitat for *Conilurus*, *Pseudomys* spp. and *Mastacomys*. Before the decimation of this pseudomyine group, *Pseudomys fumeus* may have occurred in the ferny declivities of the Pyramids hill and along Shaws Creek and the river. *Hydromys* was evidently very rarely caught by the owls, and it is the only locally-recorded modern murid not found in the whitish fraction of the deposit.

Thus there is very close coincidence between the modern small mammal fauna of the region and the species of the whitish fraction. This is essentially a faunal assemblage of dry sclerophyll forest and grassy woodland (see pp. 2-6).

The composition of the reddish fraction of the deposit shows it to be, in general, a wet sclerophyll forest faunal assemblage, belonging to habitats

TABLE 1
Number and Percentage of Species in Pyramids Cave Deposit Fractions

| | Reddish fraction | | Whitish fraction | |
|----------------------------------|------------------|------|------------------|------|
| | No. | % | No. | % |
| <i>Sminthopsis leucopus</i> | 356 | 4.2 | 237 | 9.5 |
| <i>Antechinus stuartii</i> | 1,238 | 14.5 | 311 | 12.4 |
| <i>Antechinus swainsonii</i> | 390 | 4.6 | 98 | 3.9 |
| <i>Phascogale tapostafa</i> | 19 | 0.2 | 2 | 0.1 |
| <i>Dasyurus viverrinus</i> | 1 | 0.0 | 2 | 0.1 |
| <i>Sarcophilus lanarius</i> | 1 | 0.0 | | |
| Dasyuridae | 2,005 | 23.5 | 650 | 25.9 |
| <i>Perameles nasuta</i> | 81 | 0.9 | 26 | 1.0 |
| <i>Isodon obesulus</i> | | | 20 | 0.8 |
| Peramelidae | 81 | 0.9 | 46 | 1.8 |
| <i>Acrobates pygmaeus</i> | 1,103 | 13.0 | 136 | 5.4 |
| <i>Cercartetus nanus</i> | 979 | 11.5 | 146 | 5.8 |
| <i>Cercartetus lepidus</i> | 111 | 1.3 | | |
| <i>Burramys parvus</i> | 141 | 1.7 | | |
| <i>Gymnobelideus leadbeateri</i> | 221 | 2.6 | 3 | 0.1 |
| <i>Petaurus breviceps</i> | 197 | 2.3 | 36 | 1.4 |
| <i>Petaurus norfolcensis</i> | | | 6 | 0.2 |
| <i>Petaurus australis</i> | | | 1 | 0.0 |
| <i>Pseudocheirus peregrinus</i> | 53 | 0.6 | 9 | 0.4 |
| <i>Schoinobates volans</i> | 5 | 0.1 | | |
| <i>Trichosurus</i> sp. | | | 1 | 0.0 |
| Phalangeridae | 2,810 | 32.9 | 338 | 13.5 |
| <i>Potorous apicalis</i> | 14 | 0.2 | 13 | 0.5 |
| <i>Petrogale penicillata</i> | 1 | 0.0 | | |
| Macropodidae | 15 | 0.2 | 13 | 0.5 |
| <i>Hydromys chrysogaster</i> | 1 | 0.0 | | |
| <i>Rattus fuscipes assimilis</i> | 2,225 | 26.1 | 303 | 12.1 |
| <i>Rattus lutreolus</i> | 12 | 0.1 | 52 | 2.1 |
| <i>Pseudomys oralis</i> | | | 502 | 20.0 |
| <i>Pseudomys higginsi</i> | 165 | 1.9 | | |
| <i>Pseudomys fumus</i> | 817 | 9.6 | 225 | 9.0 |
| <i>Pseudomys novaehollandiae</i> | 43 | 0.5 | 134 | 5.3 |
| <i>Melomys cervinipes</i> | 38 | 0.4 | | |
| <i>Mastacomys fuscus</i> | 97 | 1.1 | 194 | 7.7 |
| <i>Conilurus albipes</i> | 1 | 0.0 | 31 | 1.2 |
| Muridae | 3,399 | 39.9 | 1,441 | 57.5 |
| <i>Rhinolophus megaphyllus</i> | | | 1 | 0.0 |
| <i>Eptesicus pumilus</i> | 3 | 0.0 | 1 | 0.0 |
| <i>Chalinolobus morio</i> | 3 | 0.0 | | |
| <i>Chalinolobus gouldii</i> | 3 | 0.0 | 1 | 0.0 |
| <i>Nyctophilus geoffroyi</i> | 29 | 0.3 | 8 | 0.3 |
| <i>Nyctophilus timoriensis</i> | 4 | 0.0 | 3 | 0.1 |
| <i>Pipistrellus tasmaniensis</i> | 6 | 0.1 | 3 | 0.1 |
| <i>Miniopterus schreibersii</i> | 153 | 1.8 | 1 | 0.0 |
| <i>Tadarida australis</i> | 1 | 0.0 | | |
| <i>Tadarida loriae</i> | 2 | 0.0 | 1 | 0.0 |
| Microchiroptera | 204 | 2.4 | 19 | 0.8 |

considerably wetter than those of the modern fauna of the Pyramids area. The principal evidence is:

1. The predominance of *Rattus fuscipes assimilis* in the reddish fraction, where it comprises 26 per cent of the mammal count, compared with 12 per cent in the whitish fraction.

2. The strong representation of *Gymnobelideus* and *Burramys* in the reddish fraction and their low status or absence in the whitish fraction. Each requires very wet conditions, either forest or shrubbery.

3. The absence or low status in the reddish fraction of the woodland species *Petaurus norfolcensis* and *Conilurus albipes*, compared with the representation of each in the whitish fraction.

4. The low status of *Rattus lutreolus*, *Mastacomys fuscus* and *Pseudomys novaehollandiae* in the reddish fraction, compared with their strong representation in the whitish fraction. The first two favour wet grassed areas rather than dense forest, and the third is a dry forest species.

The following data, supplied by the FWD, are numbers of terrestrial mammals trapped at Loch Valley, east-central Victoria, during 1957-63. The general vegetational formation is wet sclerophyll forest and the M.A.R. is approximately 56 in.

| | |
|----------------------------------|-------|
| <i>Antechinus stuartii</i> | 83 |
| <i>Antechinus swainsonii</i> | 54 |
| <i>Perameles nasuta</i> | 13 |
| <i>Rattus fuscipes assimilis</i> | 1,408 |
| <i>Rattus lutreolus</i> | 3 |
| <i>Mastacomys fuscus</i> | 6 |

Gymnobelideus leadbeateri, *Pseudocheirus peregrinus* and *Schoinobates volans* were also recorded as present in the area.

Despite the different sampling method, the proportionate representation of the species in this list is very similar to that in the reddish fraction of the Pyramids deposit (Table 1).

Data in Table 1 demonstrate discontinuity in species composition between the two fractions of the deposit. *Cercartetus lepidus*, *Burramys parvus*, *Pseudomys higginsii* and *Melomys cervinipes* are not represented in the whitish fraction, while *Isodon obesulus*, *Petaurus norfolcensis* and *Pseudomys oralis* are not in the reddish fraction. Furthermore, no bones intermediate in physical character between those of the two fractions were found in the deposit. These two features lead to the hypothesis that there was a time gap between the respective periods of accumulation of the two fractions.

Samples of typical hard bones of the whitish fraction, when baked for 30 days at 135°C, became fragile in texture and reddish-brown in colour, as in the reddish fraction. This applied equally to bones buried in a quantity of cave dust and to bones not in any matrix. Therefore, the fragile reddish state may be brought about by chemical alteration induced by heat and is not dependent on contact with the matrix.

In summary, the data indicate the following sequence in the Pyramids area:

1. An early phase when ground-moisture conditions were wetter than at present and the vegetational formation predominantly wet sclerophyll forest, and when the mammal fauna was similar to that of modern wet forests in high rainfall areas of east-central Victoria but with *Cercartetus lepidus*, *Melomys cervinipes* and *Pseudomys higginsii* also present.

2. An intermediate phase during which the predators did not use the Pyramids Cave and during which bones in the cave became altered to fragile texture and reddish colour.

3. A late phase when ground moisture and vegetational formations approximated those of the area at present, with a dry forest and woodland fauna essentially the same as the local modern one.

The comparative abundance of *Miniopterus schreibersii* in the reddish fraction would only indicate that this bat colonized the cave at some time during the early phase, and that natural mortality or owl predation added the remains of a number to the deposit.

COLOUR ANALYSIS OF REDDISH FRACTION

Between individual bones of the reddish fraction there was considerable variation in colour, from light orange to dark reddish-brown. With the idea that this variation might be correlated with age, dentaries of the fraction were sorted into six colour categories. For each category, a small group of specimens was selected as a standard. Sorting was done, by visual comparison, according to the standard to which each dentary approximated most closely. Only clean, uniformly coloured dentaries were included in this analysis, and the total sample sorted comprised approximately two-thirds of the dentaries of the reddish fraction. By the same process, post-cranial bones and bone fragments were sorted out from the reddish fraction, to provide samples of the colour categories for radiocarbon dating.

The categories are identified by the figures 5 to 10. According to the colour standards of Ridgway

TABLE 2

Number and Percentages of Principal Species and Families in Colour Categories of the Reddish Fraction, Pyramids Cave

| Categories: | 10 | | 9 | | 8 | | 7 | | 6 | | 5 | |
|----------------------------------|-------|------|-------|------|-------|------|-----|------|-----|------|-----|------|
| | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| <u>Sminthopsis leucopus</u> | 62 | 5.4 | 67 | 4.8 | 48 | 4.0 | 21 | 2.3 | 17 | 3.7 | 0 | 0.0 |
| <u>Antechinus stuartii</u> | 166 | 14.4 | 181 | 13.1 | 196 | 16.2 | 109 | 12.1 | 52 | 11.4 | 16 | 10.4 |
| <u>Antechinus swainsonii</u> | 57 | 4.9 | 65 | 4.7 | 38 | 3.1 | 40 | 4.4 | 17 | 3.7 | 1 | 0.6 |
| <u>Phascogale tapoatafa</u> | 1 | 0.1 | 1 | 0.1 | 3 | 0.2 | 3 | 0.3 | 3 | 0.7 | 3 | 1.9 |
| Dasyuridae | 286 | 24.8 | 314 | 22.7 | 285 | 23.6 | 173 | 19.2 | 89 | 19.6 | 20 | 13.0 |
| <u>Perameles nasuta</u> | 5 | 0.4 | 6 | 0.4 | 12 | 1.0 | 9 | 1.0 | 8 | 1.8 | 3 | 1.9 |
| <u>Acrobates pygmaeus</u> | 206 | 17.9 | 178 | 12.9 | 115 | 9.5 | 53 | 5.9 | 17 | 3.7 | 4 | 2.6 |
| <u>Cercartetus nanus</u> | 104 | 9.0 | 129 | 9.3 | 135 | 11.2 | 158 | 17.7 | 79 | 17.4 | 35 | 22.7 |
| <u>Cercartetus lepidus</u> | 15 | 1.3 | 19 | 1.4 | 12 | 1.0 | 12 | 1.3 | 5 | 1.1 | 1 | 0.6 |
| <u>Burremys parvus</u> | 28 | 2.4 | 24 | 1.7 | 14 | 1.2 | 14 | 1.5 | 14 | 3.1 | 1 | 0.6 |
| <u>Gymnobelideus leadbeateri</u> | 30 | 2.6 | 30 | 2.2 | 26 | 2.1 | 25 | 2.8 | 18 | 4.0 | 0 | 0.0 |
| <u>Petaurus breviceps</u> | 27 | 2.3 | 35 | 2.5 | 29 | 2.4 | 24 | 2.7 | 9 | 2.0 | 3 | 1.9 |
| <u>Pseudocheirus peregrinus</u> | 4 | 0.3 | 9 | 0.7 | 7 | 0.6 | 7 | 0.8 | 6 | 1.3 | 3 | 1.9 |
| Phalangeridae | 414 | 35.9 | 425 | 30.8 | 338 | 27.9 | 293 | 32.6 | 150 | 33.0 | 49 | 31.8 |
| <u>Rattus fuscipes assimilis</u> | 336 | 29.2 | 462 | 33.4 | 373 | 30.8 | 247 | 27.5 | 102 | 22.4 | 25 | 16.2 |
| <u>Pseudomys higginsii</u> | 20 | 1.8 | 24 | 1.7 | 32 | 2.6 | 17 | 1.9 | 18 | 4.0 | 11 | 7.1 |
| <u>Pseudomys fumeus</u> | 76 | 6.6 | 122 | 8.8 | 146 | 12.1 | 128 | 14.2 | 70 | 15.4 | 35 | 22.7 |
| <u>Pseudomys novaeollandiae</u> | 4 | 0.3 | 11 | 0.8 | 4 | 0.3 | 4 | 0.4 | 1 | 0.2 | 1 | 0.6 |
| <u>Melomys cervinipes</u> | 4 | 0.3 | 7 | 0.5 | 4 | 0.3 | 2 | 0.2 | 1 | 0.2 | 0 | 0.0 |
| <u>Mastacomys fuscus</u> | 5 | 0.4 | 8 | 0.6 | 14 | 1.2 | 24 | 2.7 | 11 | 2.4 | 9 | 5.8 |
| Muridae | 445 | 38.6 | 636 | 46.0 | 573 | 47.4 | 423 | 47.1 | 205 | 45.1 | 81 | 52.6 |
| Total, marsupials & murids | 1,152 | | 1,382 | | 1,210 | | 899 | | 455 | | 154 | |

Note: Numbers and percentages for families, and the final totals, include data of some species not listed in the table.

(1912), the sequence ranges from Pale Yellow-Orange (category 5), through Cinnamon Buff (7) and Cinnamon (8), to Sudan Brown (10). The number of individuals of each species represented in each category was estimated by counting the dentaries. Numbers for the principal species, and for the families, together with the percentage which these represent in each category, are set out in Table 2. Certain of these data are further illustrated in Fig. 2.

It was observed that reddish-brown bones of this fraction faded to appreciably lighter colours when kept for a period of approximately two years in open boxes subject to daylight and artificial light. Similar lots kept in closed boxes did not fade. This was assessed by comparison with standards used for the original sorting. The observation suggests that bones lying at and near

the surface in the deposit would have attained lighter coloration. Furthermore, bones of category 5, as well as being of lightest colour, were in general the most fragile of the fraction, indicating greater exposure to the factors which induced change in texture.

The two observations suggest that, during the phase of alteration of the older fraction, bones became differentially coloured according to the various depths at which they lay. If the deposit remained essentially undisturbed until after the phase of alteration, variation in colour in the reddish fraction should be correlated with original stratification and hence with age. The fact that material of the whitish fraction was present throughout the deposit, particularly in the trough of the inner chamber, demonstrates that the movement of the bulk of the deposit from the outer

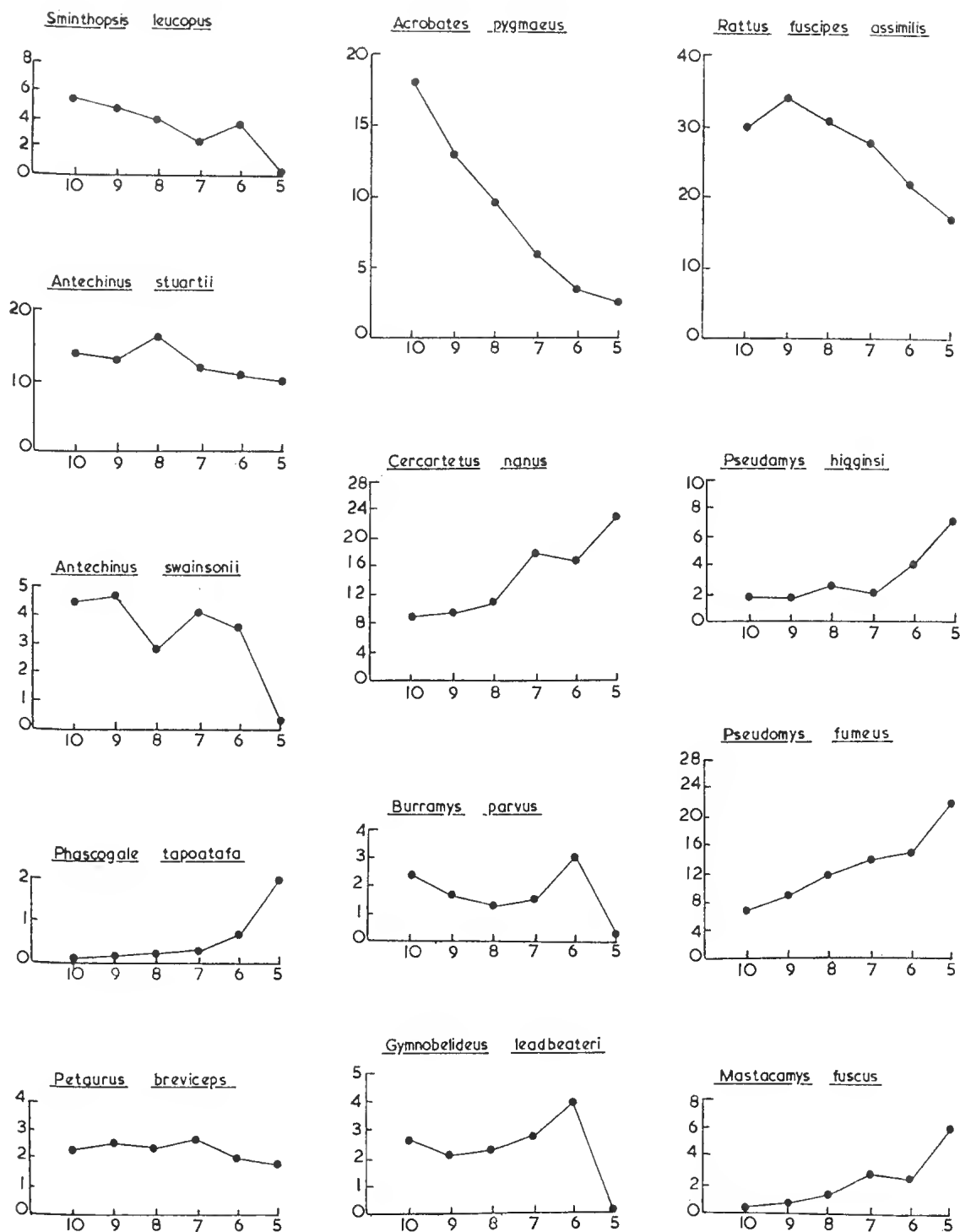


FIG. 2—Percentages of principal species in colour categories of reddish fraction of Pyramids Cave deposit. Percentages are shown on the vertical scale, and colour categories on the horizontal line, in each case.

chamber did in fact take place during or after the period of accumulation of the whitish fraction.

It would appear therefore that the six colour categories represent a chronological sequence, with category 10 the oldest and category 5 the youngest. The orderliness of results of the species analysis of the colour categories, as evidenced by steady trends in graphs of Fig. 2, support the colour-age correlation theory. The species analyses do not require absolute colour-age correlation for the individual specimens; they depend on the concept of mean age of the specimens of a species in a colour category, and such means should be independent of the amount or extent of overlap between a group of specimens and its counterparts in adjacent categories.

The following considerations arise from data in Table 2:

1. Through the sequence from category 10 to category 5, there is progressive decline in percentages of *Acrobates pygmaeus* and *Rattus fuscipes assinilis*, and there is progressive increase in percentages of *Phascogale tapoatafa*, *Cercartetus nanus* and *Mastacomys fuscus*. Statistically, this sequence of changing percentages is highly significant ($p < 0.001$).

As *Acrobates* and the *Rattus* are most abundant in dense wet forests, and the other three favour comparatively dry and/or open vegetational formations, these changes indicate that, over the period of accumulation of the reddish fraction, there was a general lessening of wet sclerophyll forest coverage in the Pyramids area.

2. Category 5 differs from the whitish fraction (Table 1) and other categories of the reddish fraction in these ways:

- (a) Absence or very low status of *Sminthopsis leucopus*, *Antechinus swainsonii*, *Cercartetus lepidus*, *Burramys parvus*, *Gymnobelideus leadbeateri* and *Melomys cervinipes*, all of which favour comparatively wet habitats. In comparison with the overall proportions in categories 6 to 10 combined, the low proportions in category 5 are significant only for the less rare species; but when the data of the six species are combined to represent a unit of wet habitats, the same comparison gives a high level of significance ($p < 0.001$).

- (b) The ratio of *Acrobates pygmaeus* to *Cercartetus nanus* is least (1:9) in category 5.

- (c) The percentage of *Phascogale tapoatafa* is highest in category 5.

Category 5 thus appears to represent a faunal assemblage of habitats drier than those represented by the other reddish categories and drier

than the average conditions during the accumulation of the whitish fraction of the deposit.

The last part of this comparison is reinforced by the close similarity in analysis between the owl pellet deposit from Victoria Range, western Victoria (Wakefield 1963b), and category 5. In both cases, murids comprise approximately half the mammal count, with *Pseudomys fumeus* the most abundant murid, while *Cercartetus nanus* contributes approximately 20 per cent of the mammal count and is the most abundant phalangerid. However, the higher percentage of *Antechinus swainsonii*, and the higher ratio of *Acrobates pygmaeus* to *Cercartetus nanus* (1:3), in the Victoria Range deposit, indicate that the latter accumulated in environmental conditions less dry than those applying to category 5. The Victoria Range area is today drier than the Pyramids area, and the fauna of the Victoria Range deposit, like that of the whitish fraction of the Pyramids deposit, is essentially the modern fauna of its area. By these comparisons, category 5 appears to represent environmental conditions much drier than modern conditions in the Pyramids area.

In summary, the colour analysis of the reddish fraction indicates (a) that during the period of accumulation of this fraction there was progressive change to less wet ground conditions and to more open vegetational formations, and (b) that the terminal stage of the accumulation represents conditions drier than the present and with the mammal fauna correspondingly modified by the elimination or marked reduction of species favouring wet forest habitats.

COLOUR VARIATION IN WHITISH FRACTION

By a process similar to that used for the reddish fraction, dentaries of the whitish fraction were sorted into four colours: category 1, glossy white; category 2, dull white; category 3, yellowish white; category 4, greyish white. Clean post-cranial bones and bone fragments were sorted from the fraction to provide a sample each of categories 2 and 3 for radiocarbon dating.

Species counts were made, and the percentage of each species determined, for each category. No significant difference was found between the categories, either in species represented or in the proportionate representation of each species.

AGE ESTIMATES

EVIDENCE FROM OTHER DEPOSITS

The faunal, vegetational and climatic sequences indicated by the Pyramids Cave data conform very closely to those indicated by study of stratified sediments and fossils of McEacherns Cave,

Nelson, south-western Victoria (Wakefield 1967c, 1969a).

Nelson is 400 miles W. of the Pyramids, and altitude, geology, climate and general vegetation are about the same in both areas. McEacherns Cave was not a predator den but a trap into which ground-frequenting animals fell. There were three groups of sediments relevant to a comparison with the Pyramids deposit:

1. Lower sediments, containing remains of large extinct Pleistocene marsupials (*Zygomaturus*, *Proteninodon*, *Sthenurus* spp., *Thylacoleo* and *Sarcophilus laniarius*), and a small-mammal fauna of the wet sclerophyll forest type, with *Rattus fuscipes* comprising 44 per cent of the total mammal count, with *Antechinus stuartii* and *Perameles nasuta* next in abundance, with *Pseudomys fumeus* present but *Conilurus* and other pseudomyine murids absent, and with *Isodon* absent. A radiocarbon date of $15,200 \pm 320$ years B.P., returned for a collection of small bones from the uppermost few inches of these sediments, identifies the sample with the latter part of the main Würm glacial period. (The age range represented in the sample may have been of the order of thousands of years, as the bones numbered several hundred and they and the associated sediments had probably been shifted to their final location by water movement.)

2. An intermediate group of sediments, comprising many thin strata of silt and fine sand, wind-eroded from various surface sediments and blown into the cave, overlain by coarse sand containing remains of semi-desert animals—*Onychogalea fraenata*, *Bettongia lesueur*, and a small form of *Isodon*. The wind-blown sediments were superimposed on the lower (Pleistocene) sediments with marked disconformity between, indicating an abrupt reduction of underground water movement.

3. Upper sediments, containing the mammal species of the modern local dry sclerophyll forest and woodland fauna, including *Conilurus albipes*, four species of *Pseudomys*, and the large *Isodon obesulus*, and with *Rattus fuscipes* represented by only 10 per cent of the total mammal count.

Fern Cave (16 miles E. of McEacherns Cave) contained a subfossil fauna essentially modern in character, with no semi-desert species or extinct Pleistocene marsupials, but *Thylacinus* was represented. This fauna is very similar, both in species composition and proportionate representation, to that of the upper sediments in McEacherns Cave (Wakefield 1964, 1967c). On the basis of the most recent dates for *Thylacinus* remains on the Australian mainland (Macintosh and Mahoney 1964, Partridge 1967, Lowry and Merrilees 1969),

the probable period of accumulation of the Fern Cave deposit may be assessed as extending from the order of 3,000 to 4,000 years B.P. to the present.

The main part of the reddish fraction of the Pyramids deposit appears to correspond to the lower (Pleistocene) sediments and fossils of McEacherns Cave. Category 5 of the reddish fraction, and the hiatus between the periods of accumulation of the two fractions of the Pyramids deposit, appear, collectively, to correspond to the phase of wind-blown dust in McEacherns Cave and to the occurrence of semi-desert fauna there. The whitish fraction of the Pyramids deposit corresponds to the faunal assemblage of the upper sediments of McEacherns Cave and to the whole of the Fern Cave deposit.

Of the semi-desert mammals appearing in McEacherns Cave, *Bettongia lesueur* may be used as an indicator of climatic conditions. It is not recorded as a modern animal in Victoria but occurred in the Murray-Darling Junction area, south-western New South Wales, in 1857, where M.A.R. is 10 in. (Wakefield 1966). Its extension south to coastal areas of western Victoria, where M.A.R. exceeds 25 in., would point to conditions drier than the present. The suggestion is strengthened by the association of the species with the wind-blown sediments in McEacherns Cave. Moreover, the absence of the species from comparatively recent south-western Victorian subfossil sites, such as Fern Cave, indicates that in this region it belonged to conditions different from those of modern time.

Bettongia lesueur has been found also, in south-western Victoria, in deposits at Skene Street, Warrnambool, and at Mount Hamilton. In both cases the range of mammals embraced extinct Pleistocene species, such as *Sthenurus* and *Thylacoleo*, and modern introduced species such as *Ovis* and *Mus*. Neither the *Bettongia* nor any extinct Pleistocene species occurred in the Tower Hill beach middens, 7 miles WNW. of Warrnambool, where the assemblage is essentially the local modern one. (Wakefield 1964.) The main Tower Hill beach midden deposit lay in the lower horizon which provided a radiocarbon date, from charcoal, of $5,120 \pm 120$ years B.P. (Gill 1971).

Bettongia lesueur occurred, as the most abundant macropodid, in an aboriginal midden underlying the tuff from the Tower Hill volcano, at Merri Creek, Bushfield, 5 miles N. of Warrnambool, and was associated there only with species which persisted in the region into modern time (Wakefield 1964). At present, the most reliable evidence of the timing of the initial deposition of tuff in that area is a radiocarbon date of $7,300 \pm$

150 years B.P. (GaK-2856) obtained from solid pieces of marine shell from an aboriginal midden in tuff at Point Pickering, Warrnambool. Apparently this site was used during the period when Tower Hill was erupting. This date is more relevant than the $6,605 \pm 90$ years B.P. previously obtained for carbonate from bones in the Bushfield midden (Gill 1971), as the latter probably dates soil carbonate which the bones had acquired rather than the bones themselves. (The date for the Point Pickering midden, and associated comments, were made available by E. D. Gill in a personal communication.) These details indicate that *Beitongia lesueur* occurred at Bushfield during a period prior to 7,300 years B.P.

The Wombeyan Caves fauna included extinct Pleistocene marsupials, and also small mammals such as *Burramys parvus*, *Cercartetus lepidus* and *Pseudomys higginsii*, and it was evidently contemporaneous with the fauna of the reddish fraction of the Pyramids Cave deposit (see pp. 22, 24).

The owl pellet accumulation at Mabel Cave, East Buchan (4 miles SSE. of the Pyramids site), which was very similar to the whitish fraction of the Pyramids deposit, both in species present and their proportionate representation (Wakefield 1960a, 1960b), was later found to comprise the uppermost layer of a stratified deposit (Wakefield 1967b). The stratigraphic position of the Mabel Cave pellet material—from surface to several inches deep—and its similarity to the whitish Pyramids fraction, add to evidence that the latter was comparatively recent in origin.

RADIOCARBON DATING

Seven samples were extracted from the Pyramids Cave deposit for dating at Gakushuin University, Tokyo. Comparatively large clean bones and bone fragments were selected from material remaining after dentaries, cranial specimens and limb-bones were segregated, and these were sorted into the various colour categories. The selection was made from throughout the complete bulk of the bone debris from the deposit, so that each sample represented the whole of its colour category.

Advice had been received from Gakushuin University that samples weighing more than 150 gm. could be assayed (K. Kigoshi, letter 27 July 1965). The process of selection was continued until samples weighing between 200 and 240 gm. were obtained. To provide sufficient weight, material representing categories 5 and 6 was bulked to constitute sample 5-6. Other samples were numbered according to the category represented. The samples were sent in three stages—first nos. 3,

5-6, 8, 10; then 2, 9; then 7. Age assays for the samples were (years B.P.):

2. (=GaK-1103) — $\begin{cases} 2,530 \pm 90 \\ 3,260 \pm 400 \end{cases}$
3. (=GaK-877) — $>33,000$
- 5-6. (=GaK-865) — $29,400 \pm 1500$
7. (=GaK-1419) — $30,300 \begin{cases} +2,400 \\ -1,700 \end{cases}$
8. (=GaK-864) — $15,450 \pm 600$
9. (=GaK-1104) — $17,700 \pm 900$
10. (=GaK-863) — $>32,900$

The younger date was reported initially for sample 2 (K. Kigoshi, letter 10 April 1967), and later (letter 17 April 1968) the older date was reported, with the explanation that the 2,530 was from carbon obtained by 'the usual H_2SO_4 extraction' while the 3,260 was obtained by 'the collagen method'. Earlier correspondence (4 July 1966) indicated that assays of bone samples were based on organic carbon.

The ages reported for sample 3 and sample 2 are incompatible. The two samples differed only in that the fragments comprising the one averaged somewhat yellowish in comparison with the average colour in the other. Each sample was extracted from throughout the whole of the whitish fraction of the deposit, there was no clear-cut differentiation in colour between the two, and all degrees of intermediate coloration were represented in the fragments allocated to the two samples. The colour categories which the samples represent are the same in faunal composition (see p. 12), the equivalent of the modern local mammal assemblage.

There is an anomaly also in the series of dates returned for samples from the reddish fraction. Again, the fragments making up each sample were obtained from throughout the whole of the bone debris of the fraction, the categories which the samples represent are not clear cut and each differs only slightly in average colour from the next. If difference in colour is, in fact, correlated with age, the series of samples (5-6, 7, 8, 9, 10) should have provided, in that order, either progressively greater or progressively smaller ages. If colour and age are not correlated, the samples, in view of the selection technique, should have given assays of the same order of age. It does not appear possible that true ages of the two samples of lightest colour (5-6 and 7) and the sample of darkest colour (10) were each about 30,000 years or more while the true ages of samples of intermediate colour (8 and 9) were each only about half as much.

Professor Kigoshi stated (letter 18 July 1966) that the following amounts of organic carbon were recovered from the first group of samples:

3. (GaK-877)—2.45 gm.
- 5-6. (GaK-865)—1.39 gm.
8. (GaK-864)—1.23 gm.
10. (GaK-863)—1.87 gm.

It was expected that, for those samples of similar qualities and comparable weights, less organic carbon would be recovered from older samples. However, for these four, the amounts were directly proportional to ages reported.

Corresponding data for later samples (letter 5 March 1968) are:

7. (GaK-1417)—1.10 gm.
9. (GaK-1104)—0.62 gm.

(The figure for sample 2 was not given.)

The carbon recovered for sample 9 (dated 17,700 years) was only one-third as much as for sample 10 (dated 32,000 years).

Additional samples are being extracted from the two fractions of the deposit, to be dated by the technique described by Haynes (1968). In the meantime, none of the radiocarbon dates already obtained for samples from the Pyramids Cave are advanced as evidence of ages of local events.

CLIMATOLOGICAL DATA

Further to the palaeoclimatic data discussed in the McEacherns Cave reports and the estimates made there (Wakefield 1967c, 1969a), the following details are relevant to assessment of dates for events in that locality and in the Pyramids area.

1. Rosholt *et al.* (1961) produced a 'generalized temperature curve' for surface waters of tropical seas, which showed (a) a period of very low temperature from 20,000 to 12,000 years B.P., corresponding to the main phase of the Würm glaciation, (b) rapid rise in temperatures from 12,000 to 10,000 years, with a thermal peak (a little below present level) 10,000 years ago, (c) a minor cold oscillation between 10,000 and 7,000 years ago, with its minimum at about 8,500 years, and (d) a period, from 7,000 years to the present, of temperatures higher than the present, with a thermal maximum about 4,000 years ago.

2. In a summary of climatic events, Dury (1967) included reference to (a) mean temperature rises of 17°C in Denmark, (b) 8°C or more in Columbia, and (c) from 'arctic to warm-temperate' in Austria, over the period 20,000 to 5,000 or 6,000 years B.P.; and he states: 'It seems

impossible to escape the conviction that Australia has experienced major shifts in low-level air temperatures, synchronous with, similar in value to, and identical in direction with those which are abundantly demonstrated for other areas of the world.'

3. Crocker and Wood (1947) postulated a 'great Australian arid period', which they suggested had occurred 'about 4,000 to 6,000 years ago'. They gave evidence of 'widespread wind erosion . . . following the wholesale destruction of the local flora', and considered that 'the aridity must have been not only extremely severe, but its onset must have been particularly sudden'. The authors included the Nelson area in their region of wind erosion.

4. After considering available data from Australian Quaternary fossil deposits, Tedford (1967) concluded that 'as nearly as can be determined, the extinction of such genera as *Diprotodon*, *Sthenurus*, *Procoptodon* and *Protomnodon* took place at the very end of the last glacial period, a time surprisingly close to the average date of extinction for the larger placental herbivores of North America'.

5. Lundelius (1967) summarizes data of the late-Pleistocene and post-Pleistocene faunal sequence of central Texas. The post-Wisconsin (Würm) faunal history there involves (a) extinction of giant Pleistocene species, (b) northward withdrawal, or shrinkage to local refugia, of certain species dependent on wetter and cooler climates, and (c) augmentation of the remaining recent fauna by arrival of new forms. This is interpreted as showing a gradual drying of the climate, and an 'increase in seasonality' resulting in destruction of essential habitats by summer extremes. Pleistocene extinction in central Texas appears to coincide with that of other areas of North America, and the Texas data indicate that the widespread extinction coincided with the beginning of the climatic change at the end of the Pleistocene. In central Texas, all the dated fossil deposits containing extinct species are older than 10,000 years, and all faunas younger than 7,800 years contain only Recent (Holocene) species. (None of the Texan faunas belong to the critical period between these two dates.) There is no evidence from the Texas faunas that the climate of 4,000 to 6,000 years ago was drier or warmer than at present but there is evidence of wetter conditions about 5,000 years ago, which supports others' conclusions that in south-western North America the Altithermal was comparatively wet.

6. Studies of eucalypt pollen by Churchill (1968) demonstrate that in south-western Aus-

tralia the climate from at least 6,000 years B.P. until 4,000 B.P. was wetter than at present.

The characteristics of the reddish fraction of the Pyramids deposit (see p. 12) are what would be expected in a deposit accumulated during the general phase of rising world temperatures noted by Rosholt *et al.* and Dury. The extent of change in faunal composition in the fraction, indicated by the colour analysis, suggests a period of accumulation including all or most of the recession phase following the peak, about 20,000 years ago, of the main Würm glaciation.

The aeolian sediments found in McEacherns Cave require that there was a phase of wind erosion of surface sediments as postulated by Crocker and Wood, and the abrupt disconformity between those sediments and the essentially uniform underlying Pleistocene stratum in the cave

strongly support the contention of sudden aridity. The abrupt collapse of the wet forest fauna of the Pyramids area, evidenced by the nature of category 5 of the deposit there, would be consistent with a sudden onset of aridity. The McEacherns Cave sediments indicate that there was only a single phase of severe aridity, and the evidence of wet climate in south-western Australia 4,000 to 6,000 years ago, and of *Bettongia lesueur* at Bushfield more than 7,300 years ago, indicates that this phase was much earlier than the time suggested by Crocker and Wood.

The faunal and climatic sequences which Lundelius outlines for central Texas are so similar in detail to those which local cave deposits indicate for south-eastern Australia that the coincidence must be considered. The close analogy strengthens Tedford's suggestion that extinctions of large mar-

TABLE 3
Proposed Correlation of Pyramids Cave Data

| Events at Pyramids Cave | Mammals of Pyramids area | Vegetation (Pyramids) | Climate (SE. Aust.) | Contemporaneous events | Epoch |
|---|---|---|---|--|---|
| Owls again occupy cave, accumulation of new pellet material in outer chamber, no alteration of bones, mixing together of old and new material by gravitational movement from outer to inner chamber probably assisted by possums. | Small mammal fauna similar to modern dry forest and woodland assemblage, presence of some species (<i>Petaurus norfolcensis</i> , <i>Isaodon obesulus</i> , <i>Pseudomys oralis</i>) not previously in evidence. | Mainly woodland and dry sclerophyll forest, as at present. | Average conditions similar to those of modern times. | Accumulation of upper sediments in McEacherns Cave, of complete Fern Cave deposit, and of owl-pellet layer in Mabel Cave, each with fauna equivalent to modern local assemblage. | H O L O C E N E |
| Owls absent, bones in existing deposit altered to fragile texture and reddish colour, those near surface attaining greater fragility and paler colour. | Not known. | Not known. | Drier than at present. | Presence of semi-desert mammals in SW. Vict., age assessment of > 7,300 B.P. for bones at Bushfield. | |
| Following lowering of talus, occupation of cave by owls, accumulation of stratified deposit of pellet material in outer chamber, little or no movement of bones to inner chamber. | Disappearance of species dependent on wet forest habitats. | Destruction of forest habitats. | Abrupt change to aridity. | McEacherns Cave deposition changes abruptly to wind-borne dust. | |
| Talus reaches close to outer chamber. | Essentially wet forest fauna but progressively changing to assemblage of less wet habitats; <i>Sarcophilus lanianus</i> , <i>Cercartetus lepidus</i> , <i>Pseudomys higginsi</i> and <i>Melomys cervinipes</i> present. | Formation mainly wet sclerophyll forest but long-term change to more open, less wet vegetation. | Colder than at present but with progressive change to less cold conditions. | Accumulation of lower sediments in McEacherns Cave, with wet forest fauna and extinct giant species, age ~ 15,200 B.P. for associated bones; Wombeyan faunas include <i>Cercartetus lepidus</i> , <i>Pseudomys higginsi</i> and extinct giant species. | P L E I S T O C E N E |

supials in Australia and of large placentals in North America were contemporaneous. If these events were indeed associated with a global pattern of climatic change, similar effects might be expected at comparable latitudes in the two continents.

CONCLUSION

The available evidence leads to the proposed correlation, set out in Table 3, between Pyramids Cave data and other events. There appears to be general harmony in this synthesis, and it is presented as the simplest interpretation of the data.

The small mammal assemblage represented in the reddish fraction of the Pyramids deposit is identified as Pleistocene. It was evidently a component of a fauna which embraced large marsupials such as *Zygomaturus*, *Sthenurus* and *Thylacoleo*. The fraction was probably accumulated, mainly or wholly, during the recession from the peak of the main Würm glaciation, from approximately 20,000 to the order of 10,000 years ago.

Extinction of the large marsupials, and fragmentation of the small assemblage (including disappearance of *Cercartetus lepidus* and *Pseudomys higginsii* from the Australian mainland and withdrawal northwards of *Melomys cervinipes*), appear to be related phenomena, associated with an early Holocene phase of aridity. These events may have been contemporaneous with similar events in North America approximately 8,000 to 10,000 years ago.

The assemblage of small mammals represented in the whitish fraction of the Pyramids deposit is identified as Holocene. It is evidently a component of a fauna comprising local species which survived the collapse of the Pleistocene fauna, and others (such as *Isoodon obesulus* and *Pseudomys oralis*) which moved in from elsewhere. The actual period of accumulation of the whitish fraction of the deposit is not assessed, but it is likely to have been several thousand years.

PLEISTOCENE AND HOLOCENE SERIES

From the material of each species represented in each fraction of the deposit, a series of cranial specimens and dentaries was selected for measurement and comparison of population parameters. Series are referred to as Pleistocene or Holocene, according to fraction. With minor exceptions the selection was limited to right dentaries and specimens which included the right maxilla. Series of modern museum specimens were included in the study. Unless otherwise indicated, modern series are Victorian, and the registered numbers cited in this section are those of the NMV.

Measurements were made with dial calipers or vernier calipers, correct to one-tenth millimetre. Unless otherwise indicated, measurements given are in millimetres. In general, quantitative comparisons in this section apply to means for the series concerned. Differences were assessed by the Student's *t* test, and those commented upon without qualification in this section are of high statistical significance, with $p < 0.01$.

The details set out are salient points extracted from a large volume of unpublished statistical data (Wakefield 1969b). For most species, especially where large numbers of specimens were involved, some significant differences were observed between the various series compared. Most of the differences however are of the order of those expected between local populations of a subspecies, and are less than those which usually distinguish primary subdivisions (=subspecies) of a species.

Ride (1960) noted that most specimens from Wombeyan Caves were subadult. This applies to owl pellet deposits in general, but it concerns marsupial specimens rather than murids. As a result, for many marsupial species, mean dimensions of bones subject to growth during subadult to adult stages were smaller in most Pyramids series than in modern museum series. In these cases, proportions of cranial bones and dimensions of teeth have been the main criteria for the comparisons.

DASYURIDAE

Sminthopsis leucopus

Teeth of the Pleistocene series are similar in size to those of a modern series from central and western Victoria, but lengths of molar rows of the Holocene series are 6 per cent less, suggesting an east-west dichotomy in the more recent Victorian populations.

Antechinus stuartii

Molar rows in the Pleistocene series are 2-3 per cent longer than in the Holocene series, but the M^{1-3} lengths of both series fit into the north-south size cline found in the species by Wakefield and Warneke (1967).

Antechinus swainsonii

The two Pyramids series are closely similar, but each has larger dentaries, larger molars and a more abruptly elevated coronoid process than in a modern series from Loch Valley, east-central Victoria. Wakefield and Warneke (1963) found that populations of the species from various south-eastern Australian localities differed without apparent pattern in features such as tooth-size.

PERAMELIDAE

Perameles nasuta

In the Pleistocene series, dentaries and premolar rows are 20 per cent shorter, and molar rows 11 per cent shorter, than in a modern series. No specimens with

mature dentition occurred in the Holocene fraction, but specimens from Basin Creek (in NMV) demonstrate that modern *P. nasuta* of the Pyramids area is large, as in other parts of Victoria. The smaller dimensions in the Pleistocene series may be due partly or wholly to an age bias between samples.

PHALANGERIDAE

Cercartetus nanus

The small modern series available is bimodal, with teeth dimensions in four specimens from eastern Victoria and eastern N.S.W. averaging 9 per cent more than in eight specimens from elsewhere in Victoria. The Holocene series corresponds in tooth-size to the four eastern specimens, but teeth dimensions in the Pleistocene series are 5 per cent more.

Burrarnys parvus

The modern Mt. Hotham specimen (C7290) is larger in limbs and molar teeth but smaller in premolars and it has a proportionately longer and narrower palate than the Pleistocene Pyramids *Burrarnys*. Differences are of various levels of significance.

Gymnobelideus leadbeateri

Teeth measurements of the Pleistocene series are 0.9 per cent more than in a modern series, with various levels of significance.

Petaurus breviceps

In the Pleistocene series, molars are not significantly larger, but fourth premolars are 7 per cent longer and wider than in the Holocene series, and the limb-bones are shorter by 7.10 per cent than in the Holocene and modern series. The apparent evolutionary elongation of limb-bones is being studied further.

Schoinobates volans

The Pleistocene series (dentaries only) has the molar row 7 per cent shorter than in a modern series. Seven Basin Creek specimens (in NMV) demonstrate that modern Pyramids district specimens have the larger molar size. The Pleistocene *Schoinobates* approaches in tooth-size the *S. volans minor* of north-eastern Queensland, a specimen of which, according to Thomas (1888) has molar teeth 10 per cent smaller than in the nominate race.

Pseudocheirus peregrinus

Teeth measurements in the Holocene series are 5.10 per cent more than in a modern series from central and south-eastern Victoria, indicating geographical variation in the recent population. The Pleistocene series has molars intermediate in size, but the P_4 smaller, than in either of the later series.

MACROPODIDAE

Potorous apicalis

The diagnostic P^4 of *P. apicalis* occurs on one Holocene Pyramids specimen, and there are specifically identified specimens also from other recent deposits in the area. However, as there is no P^4 available in the older fraction, the identification of the Pleistocene

Pyramids series as *P. apicalis* rather than *P. tridactylus* is tentative. Teeth of the Pleistocene series are, on the average, smaller than those of the Holocene and of modern series of *P. apicalis*.

MURIDAE

Hydromys chrysogaster

Size of the single M^1 (Pleistocene) approximates to the minimum observed in a modern series.

Rattus fuscipes assimilis

The zygomatic plate is proportionately longer in the Pleistocene series than in the Holocene and a modern series.

Pseudomys fumeus

The Pleistocene and Holocene series are generally similar, but they differ, collectively, from the topotypical modern western Victorian series by smaller sizes of teeth and cranial bones.

Pseudomys higginsii

This presumably extinct mainland population is discussed elsewhere (Wakefield 1972). Its teeth are larger and the zygomatic plate proportionately longer than in the modern Tasmanian population.

Pseudomys oralis

In the holotype (BM, 47.1.20.2), M^{1-3} length (alveolar) is 6.8, and the interorbital constriction is 3.7 (J. E. Hill, letter 12 March 1965). M^{1-3} length in the Holocene series is similar (mean 6.9) but the interorbital constriction broader (n, 15; mean, 4.26; s.d., 0.18).

Pseudomys novae-hollandiae

The Pleistocene and Holocene series are similar in teeth measurements, and these are 5 per cent more than in a topotypical series from north-eastern New South Wales, according to measurements of Keith and Calaby (1968).

Conilurus albipes

Specimens of the Holocene series, submitted to the BM, 'suggest a larger, wider skull with longer tooth-rows' than available comparative material 'including BM 42.6.29.8, described by Tate (The Rodents of Australia and New Guinea, *Bull. Amer. Mus. Nat. Hist.* 1951, 97: 183-430, p. 270) in which M^{1-3} (crowns) is 8.5 mm and not 9.5 as he states (pp. 270, 370)' (J. E. Hill, letter 13 July 1967).

Mastacomys fuscus

In the Pleistocene series teeth are smaller and the zygomatic plate proportionately longer than in the Holocene series, while the latter is generally similar to a modern series from the Australian mainland. The populations of the species are reviewed elsewhere (Wakefield 1972).

Other species in the Pyramids deposit showed little variation between series from the two fractions or between these and modern museum series.

WOMBEGAN CAVES

MAMMALS OF THE FOSSIL BRECCIA

Broom (1896a, 1896b, 1896c) described specimens of marsupials from a deposit of bone breccia at Wombeyan Caves, eastern New South Wales, and Ride (1956a, 1956b, 1960) made further study of material from the same source. Some of Broom's specimens (in AM), and certain additional ones studied by Ride, have been examined, and in this section a summary is presented of the species and their principal characters. In most cases the characters are assessed on the basis of data from pp. 17-18, and the same system of annotation is used, except that the unqualified specimen numbers hereunder are those of the AM.

Besides adjustments arising from synonymies discussed later (pp. 20-22), three alterations are made here to identifications of Ride (1960). A specimen (B61) included then in the *Antechinus flavipes* series is identified as *Sminthopsis murina*, one (B8/g) included then in the *Pseudomys oralis* series is identified as *Pseudomys higginsii*, and the series then named *Gyomys glaucus* is identified as *Pseudomys fumeus*. Schram and Turnbull (1970) also used the name *Gyomys glaucus* for a series of *Pseudomys fumeus* from the Wombeyan Caves breccia.

Sminthopsis murina

Ride's B61, a dentary, has tooth-sizes and comparatively short premolar row as in a modern south-eastern Australian series of *S. murina*. In *S. leucopus* the premolar row is relatively long.

Antechinus flavipes

The typical molar row lengths and the diagnostic proportionate lengths of premolar rows confirm the identity of Ride's B59 (maxilla) and B18 (dentary).

(Phascogale tapoatafa)

The specimens reported by Ride (1960) were not examined.

Isodon macrourus (syn. *Perameles wombeyensis* Broom)

Comparatively large tooth-sizes and the montane habitat identify F4198 and Ride's B24 as *I. macrourus* rather than *I. obesulus*, but the diagnostic M⁴ is not available in the Wombeyan specimens to confirm the identification. (See p. 20, under *Perameles wombeyensis*.)

Perameles nasuta

The angle at which the anterior edge of the coronoid process ascends from the line of the ramus and the curvature of the lower edge of the posterior part of the ramus, in F51878, and the form of the three premolars in F51879, identify the two specimens as *P. nasuta*.

Cercartetus nanus

F17502, Ride's B17/i, B17/ii (maxillae), B16 and B56 (dentaries), have the large tooth-size of the Pleistocene Pyramids series.

Cercartetus lepidus

The few available measurements of Ride's B8 are closely similar to those in the Pleistocene Pyramids series.

Burrainys parvus

Five specimens—F3984 (type), F45778 (dentaries), F45777 and Ride's B59 and B8a (maxillae)—have teeth smaller than those of the Pleistocene Pyramids series, but proportions are closely similar. However, measurements noted by Ride (1957a) for a specimen (B57) not available during the present study, indicate a proportionately very long diastema.

Gymnobelideus leadbeateri (syn. *Palaeopetaurus elegans* Broom)

F17501 and Ride's B46 (dentaries) are not separable from a modern Victorian series (topotypical). See pp. 20-21, under *Palaeopetaurus elegans*.)

Petaurus breviceps

Ride's B18 (maxilla) has tooth-sizes smaller than means found in Pyramids and modern Victorian series.

Schoinobates volans

The identification of F5188 (dentary) is discussed under *Pseudocheirus antiquus* on page 21.

Pseudocheirus peregrinus (syn. *Pseudocheirus antiquus* Broom)

F4196 and Ride's B16 (maxillae) have tooth-lengths 12-15 per cent more than in the modern central and south-eastern Victorian series, and the intermediate sizes in the Pyramids series suggest a clinal gradient in this feature. (See p. 21, under *Pseudocheirus antiquus*.)

Potorous tridactylus

F4201 and Ride's B17 (maxillae), and F51880 (dentary), have tooth-sizes less than in a modern south-eastern Australian series of *P. tridactylus*. (See p. 21.)

Wallabia bicolor (syn. *Macropus wombeyensis* Broom)

F4199 (dentary) is typical of the eastern Australian population. (See p. 21, under *M. wombeyensis*.)

Rattus fuscipes

Three molar teeth have been examined from the specimens identified by Schram and Turnbull (1970) as *Rattus* sp. These are comparable in dimensions with those of *R. fuscipes*. Four maxillae from the recently discovered Wombeyan Caves quarry deposit (Hope 1971) are identified, on the evidence of posterior shape of incisive foramina, as *R. fuscipes*.

Pseudomys oralis

Except for narrower incisive foramina, dimensions and proportions in Ride's B58/b (incomplete skull) and B58/c (dentary) correspond closely to data of the Holocene Pyramids series.

Pseudomys higginsii

Three measurements and one ratio, available in Ride's B8/g (dentary), are almost coincident with means in the Pleistocene Pyramids series. Four maxillae from the Wombeyan Caves quarry deposit confirm that there was a population in that locality of the Pyramids form of *P. higginsii* (Wakefield 1972).

Pseudomys fumeus

Ride's D8/6, D20/zii (maxillae), D20L, B59/i and B59/ii (dentaries), have teeth dimensions approximately 10 per cent less than in modern topotypical western Victorian series but similar to those of the two Pyramids series.

***Mastacomys fuscus* (syn. *M. wombeyensis* Ride)**

See also pp. 21-22. Specimens from the Wombeyan Caves quarry deposit have similar characters (comparatively small teeth and proportionately long zygomatic plate) to those of the Pleistocene Pyramids series (Wakefield 1972).

TAXONOMY OF WOMBEYAN NOVELTIES***Perameles wombeyensis* Broom**

In the original diagnosis Broom (1896c) used several specimens (syntypes), which he figured in Plate VIII of his paper.

The Figs. 1 and 8 of that plate are of F4198 (AM), an incomplete dentary with the M_2 present. The abruptly elevated coronoid process identifies the specimen as *Isodon* and not *Perameles*, and the size of the molar (length 2.8 mm) is that of *I. macrourus*. *I. macrourus* is widely distributed in the Blue Mountains, while the smaller *I. obesulus* is typically lowland and near-coastal.

Broom's Fig. 2 is of a specimen with upper premolars and canine, which teeth Broom described. This specimen was not available for the present study but it appears to be of *I. macrourus*.

Broom's Figs. 3 and 4 are of F51879 and F51878 respectively, which are incomplete dentaries of *Perameles nasuta* (see p. 19, and Pl. 3, fig. 2, 4, this paper).

Broom's Figs. 5, 6 and 7, are single teeth, apparently of *P. nasuta*.

Broom described *P. wombeyensis* as 'a little larger than *P. obesula*' (i.e. *Isodon obesulus*), and in particular the upper canine and the P^1 (length 2.8 mm) were said to be longer than those of *obesulus*. These data, and features of the coronoid process, were obtained from the specimen of his Fig. 2 and F4198. Broom did not compare *wombeyensis* with *macrourus* (or its synonym, *torosus*).

F4198 (Pl. 3, fig. 1, this paper) is here nominated LECTOTYPE of *Perameles wombeyensis* Broom. The specimen of Broom's Fig. 2 remains as a PARATYPE; and F51878 and F51879, as well

as the specimens of Figs. 5, 6 and 7, are excluded from the diagnosis.

Perameles wombeyensis should be placed in the synonymy of *Isodon macrourus*.

Palaeopetaurus elegans

Broom (1896b) described *Palaeopetaurus elegans* from five specimens, three of which he figures in Plate XLVI of his paper, as follows: Fig. 1. Cranial fragments and teeth, pieced together. Fig. 2. An incomplete dentary. Fig. 3. Dentary fragment with M_1 and M_2 .

Of the syntype specimens, that of Fig. 2 of the plate is F17501 (AM), and that of Fig. 3 is Ride's B46, noted earlier (p. 19) as *Gymnobelideus leadbeateri*. The location of the specimen(s) comprising Broom's Fig. 1 is unknown.

F17501 is not distinguishable in any observed detail from *Gymnobelideus leadbeateri*, having the same almost straight incisor, low coronoid process, and slightly deflected angle, which distinguish this species from *Petaurus breviceps*. The shape of the masseteric fossa of the specimen is also as in *Gymnobelideus*. McCoy (1867) did not illustrate this feature accurately in the original diagnosis of *G. leadbeateri*, which misled Broom, who noted the difference between his specimen and McCoy's illustration.

Broom noted that in *Palaeopetaurus elegans* the 'frontal bones . . . present a remarkable resemblance to those of *Gymnobelideus*, and differ from those of *Petaurus* in the absence of the post-orbital ridge'.

He described characters of the upper teeth from the specimen illustrated in his Fig. 1. The P^1 is described as 'single-rooted', but this is modified later (Broom 1896c) to 'its two roots were united together'. The P^3 of the original diagnosis had a 'very low crown as in *Petaurus*' and 'two well developed divergent roots'. The M^1 is described as 'having the two inner cusps very small and brought together', and the M^2 as 'apparently similar to' the M^1 . Later, Broom (1896c) referred to 'two other specimens of *Palaeopetaurus elegans*' in which the P^1 of the one had 'the roots close together but distinct', while the P^1 of the other had 'the roots somewhat apart'.

Broom (1896c) recorded two specimens of *Petaurus breviceps* from the Wombeyan breccia: 'an imperfect fragment of a lower jaw', and 'a fragment of the cranium with the frontal bones almost perfect', but he did not record any maxilla or upper teeth. The evidence indicates that the three maxillary specimens which he attributed to *Palaeopetaurus elegans*, including the syntype of his Fig. 1, are in fact *Petaurus breviceps*. (In *P. breviceps* both P^1 and P^3 are 2-rooted, while in

Gymnobelideus each is single-rooted.) However, there remain some anomalies in that Broom's description of the M^1 fits the M^1 of *Gymnobelideus* rather than that of *Petaurus breviceps*, while the 'apparently similar' M^2 would fit neither *Petaurus* nor *Gymnobelideus*, each of which has that tooth more square in cross-section.

F17501 (Pl. 3, fig. 3, this paper) is here nominated LECTOTYPE of *Palaeopetaurus elegans*. Ride's B46 remains as a PARATYPE, and the specimen(s) comprising Broom's Fig. 1, and its features, are excluded from the diagnosis.

Palaeopetaurus elegans should be placed in the synonymy of *Gymnobelideus leadbeateri*.

Pseudocheirus antiquus Broom

Broom (1896c) based this on several specimens, including F4196 and F51881 (AM), which he illustrated in Fig. 4, and in Figs. 6 and 8, of Plate VII of his paper. (F51881 now lacks the molar which Broom illustrated with it.)

The proportion P^3 width/ P^4 width ($=0.71$) in F4196 identifies this specimen as *Pseudocheirus peregrinus* rather than *Schoinobates volans*. In modern Victorian series of these species, means of this proportion were equivalent to 0.80 and 0.90 respectively.

The 'angle of jaw relatively small and passing backwards but a short distance' of Broom's diagnosis applies to specimen F51881, and this is, in fact, a diagnostic character of *Schoinobates volans* (Wakefield 1960a). (See Pl. 3, fig. 8, this paper.)

Other characters by which Broom sought to distinguish the *P. antiquus* from *P. peregrinus* appear to reflect characters of individuals used in the comparisons rather than true differences between populations, and a number of the characters which he found in the Wombeyan specimens (for example, the P^1 close to P^3 , and the molar cusps well developed) are what one would expect in specimens of somewhat young individuals. A modern specimen from New South Wales (AM, M3006) has the P^1 placed as in P4196, and another (AM, M4099) has molar cusps precisely as in P4196.

P4196 (Pl. 3, fig. 7, this paper) is here nominated LECTOTYPE of *Pseudocheirus antiquus*, and F51881 and its features are excluded from the diagnosis.

Pseudocheirus antiquus should be placed in the synonymy of *Pseudocheirus peregrinus*.

Burrarnys parvus Broom

This name remains valid for the species.

Potorous tridactylus var. *antiquus* Broom

AM specimens F4201 (maxilla) and F51880 (dentary) are two of the syntypes of *Potorous*

tridactylus var. *antiquus* and teeth of these were illustrated in Plate VI (Figs. 4 and 6, and 7, respectively) of the original diagnosis (Broom 1896c). Broom distinguished the 'var. *antiquus*' on the basis of the short P^4 with four grooves. The number of grooves is variable within populations of the species, however.

The shape of the P^4 of F4201 indicates that it is *P. tridactylus* rather than *P. apicalis*, but its length (6.3 mm) and the P_4 length in F51880 (5.2) are 15 and 17 per cent less than corresponding means in a modern south-eastern Australian series of *P. tridactylus* ($p = 0.040, 0.038$). Dimensions of other teeth (dP^4, M^1) of the Wombeyan specimens are 5-10 per cent less than for modern *P. tridactylus* but the differences are not significant.

F4201 (Pl. 3, fig. 5, this paper) is here nominated LECTOTYPE of *Potorous tridactylus* var. *antiquus*, and F51880 (Pl. 3, fig. 6) remains as a PARATYPE.

P. tridactylus gilberti of Western Australia has premolars short as in the Wombeyan specimens, and considerable intraspecific variation is found in other potorine macropodids from fossil deposits, for example, *Bettongia lesueur* (Wakefield 1964). Pending study and understanding of these matters, the Wombeyan *antiquus* cannot justifiably be distinguished taxonomically from *P. tridactylus tridactylus*.

Macropus wombeyensis Broom

AM, F4199 (dentary) is one of several syntypes of *Macropus wombeyensis*, and details of it comprise Figs. 2 and 3 of Plate VI of the diagnosis (Broom 1896c). Other syntypes have not been available for examination, but Broom's measurements of them are similar to those of F4199.

The available specimen is closely similar to modern examples of *Wallabia bicolor* from eastern New South Wales. For example, length of P^4 , of M^{1-3} (crown), and the crown length of the tooth-row (P^4-M^3), are 7.0, 21.2 and 38.1 mm in F4199, and 7.0, 21.9 and 37.8 in M5222 (AM) from Wyong.

F4199 (Pl. 3, fig. 9, this paper) is here nominated LECTOTYPE of *Macropus wombeyensis*. The name should be placed in the synonymy of *Wallabia bicolor*.

Mastacomys wombeyensis Ride

The species was distinguished (Ride 1956b) on the basis of a single maxilla (AM, F42322) having an additional small cusp on the M^3 and a proportionately 'wide' (i.e. long) zygomatic plate. Two further specimens from the Wombeyan Caves breccia are identified as *M. wombeyensis* by Seham and Turnbull (1970), each with the additional cusp more or less developed.

In a review of the taxonomy of *Mastacomys* (Wakefield 1972), *M. wombeyensis* is placed in the synonymy of *M. fuscus*. This conclusion is supported by a series of 20 maxillary specimens from the Wombeyan Caves quarry deposit, only two of which possess the auxiliary cusp.

AGE OF WOMBEYAN FOSSIL FAUNA

Wombeyan Caves is situated at 2,000 ft elevation, 4 miles on the seaward side of the Great Dividing Range, eastern New South Wales, in an area of Silurian limestone approximately 2 miles long and $\frac{1}{2}$ mile wide, in a general region of granitic rock (Carne and Jones 1919).

The few annual rainfall figures for Wombeyan Caves correspond closely to those for the same years at Taralga, 11 miles distant, so Taralga's mean of 30.5 in. per annum for a 73-year period may be taken to approximate closely to that for Wombeyan Caves for the same period. This figure is close to the mean for Buchan (32.1 in.) over about the same period (78 years in this case), and would approximate also to the mean for the Pyramids area.

The site of the Wombeyan deposit is in a slight depression on a ridge overlooking the valley of Wombeyan Creek (Pl. 2). It is approximately 30 chains (600 m) from the edge of the acid rock across the valley, and only 10 chains (200 m) from a tongue of acid rock in the other direction. The vegetational formation on the limestone is woodland, with *Eucalyptus melliodora* dominant and shrub thickets about the actual rock outcrops. The granitic formation carries dry sclerophyll forest. Before it was cleared, the small creek valley below the Wombeyan site would have carried elements of warm-temperate rainforest.

Distributional data presented by Marlow (1958) show that the modern small marsupial fauna of the southern part of the Blue Mountains, where Wombeyan is situated, is very similar in species composition to that of eastern Victoria (see pp. 2-6).

Thus there is very close similarity in geology, topography, climate, vegetation and modern mammal fauna, between the Pyramids and Wombeyan Caves areas, and it may be expected that contemporaneous faunas and vegetational formations in the two areas would have been very similar in the past.

Ride (1960) concluded that owls were mainly responsible for the Wombeyan deposit, and similarity to the Pyramids deposit, both in species composition and maximum size of individuals, indicates that the same species of owl, or species of very similar habits, were responsible for the two deposits. Because of the similar sampling pro-

cess, the age of the Wombeyan Caves breccia deposit may be considered in the light of data and hypotheses applying to the Pyramids deposit. Relevant points are:

1. *Cercartetus lepidus* and *Pseudomys higginsii* occur in the Wombeyan breccia and in the older fraction of the Pyramids deposit. Neither species is recorded either as a modern living animal on the Australian mainland or in any mainland fossil deposit representing a modern-type faunal assemblage.

2. *Burramys parvus* and *Gymnobelideus leadbeateri*, existing today only as relict populations, appear in the Wombeyan deposit and in the older Pyramids fraction.

3. The Wombeyan Caves quarry deposit (Hope 1971) contained fossils of large Pleistocene species (*Zygomaturus*, *Sthenurus*, *Palorchestes*, *Sarcophilus lanianus*) associated with elements of the small-mammal fauna of the Broom breccia (*Burramys parvus*, *Pseudomys higginsii* and others).

4. *Rattus fuscipes assimilis*, *Acrobates pygmaeus* and *Antechinus stuartii*, the three most abundant mammals in the older Pyramids fraction, are rare or absent in the Wombeyan breccia deposit. Each is widespread in south-eastern Australia and each is an index of wet forest conditions (see pp. 3, 5).

5. *Phascogale tapoatafa*, *Cercartetus nanus*, *Pseudomys higginsii*, *Pseudomys fumeus* and *Mastacomys fuscus*, each present in the Wombeyan breccia, increased in relative abundance in the older Pyramids fraction when, according to evidence from the colour analysis (p. 12), conditions were becoming less wet. Of these species, *Pseudomys fumeus* is the most abundant and *Cercartetus nanus* is second in abundance, in the Wombeyan sample listed by Ride (1960), and these two are similarly placed in the analysis of the deposit from the comparatively dry Victoria Range habitat (Wakefield 1963b).

6. *Pseudomys oralis*, present in the Wombeyan deposit and the most abundant mammal in the younger Pyramids fraction, is absent from the older Pyramids fraction. *Antechinus flavipes*, whose south-eastern Australian habitats are dry sclerophyll forest and woodland (Wakefield and Warneke 1967), and *Sminthopsis murina* of similar ecology, were present in the Wombeyan breccia deposit and absent from the whole of the Pyramids deposit.

7. *Burramys parvus* and *Gymnobelideus leadbeateri*, present in the Wombeyan breccia, reached their highest percentages in category 6 of the older Pyramids fraction, immediately preceding

TABLE 4

Location and Precipitation Data of Places Mentioned in Text

| Location | Lat. S | Long. E | Precip. ins. | Location | Lat. S | Long. E | Precip. ins. |
|--------------------|--------|---------|-----------------|----------------------|--------|---------|-----------------|
| Bacchus Marsh | 37°41' | 144°27' | 20.0 | Mount Hamilton | 37°47' | 143°00' | 21* |
| Bairnsdale | 37°50' | 147°38' | 27.1 | Mount Hotham | 36°58' | 147°08' | 58.5 |
| Basin Creek (head) | 37°36' | 148°15' | 40* | Mount St. Bernard | 37°00' | 147°05' | 58* |
| Bass River | 38°29' | 145°27' | 41* | Murray-Darling Jn. | 34°07' | 141°55' | 10* |
| Beech Forest | 38°38' | 143°34' | 67.6 | Murrindal River | 37°25' | 148°12' | 34* |
| Bega | 36°40' | 149°50' | 34.5 | Nagilloc | 34°28' | 142°21' | 11* |
| Bendock | 37°09' | 148°53' | 27.8 | Narracan | 38°15' | 146°14' | 41.6 |
| Bete Bolong | 37°34' | 148°19' | 33* | Nelson | 38°04' | 141°01' | 28.9 |
| Brit Brit | 37°27' | 141°46' | 24* | Nowa Nowa | 37°44' | 148°05' | 31* |
| Broadford | 37°13' | 145°03' | 24.5 | Orbost | 37°42' | 148°27' | 33.0 |
| Buchan | 37°30' | 148°10' | 32.1 | Otway Ranges | 38°40' | 143°30' | |
| Carisbrook | 37°02' | 143°49' | 20* | Ouyen | 35°04' | 142°20' | 13.0 |
| Cashmore | 38°19' | 141°29' | 32* | Pomonal | 37°12' | 142°37' | 28.2 |
| Casterton | 37°35' | 141°24' | 24.5 | Portland | 38°21' | 142°36' | 35.7 |
| Cavendish | 37°31' | 142°02' | 25.8 | Pyramids | 37°27' | 148°12' | 33* |
| Colbinabbin | 36°35' | 144°49' | 18.9 | Shepparton | 36°23' | 145°25' | 19.9 |
| Dadswells Bridge | 36°55' | 142°31' | 20.0 | Silverband Falls | 37°11' | 142°31' | 36* |
| Falls Creek | 36°52' | 147°17' | 94.4 | Stoneyford | 38°20' | 143°20' | 28* |
| Ferny Creek | 37°52' | 145°21' | 50* | Stradbroke Island | 27°30' | 153°30' | |
| Forrest | 38°31' | 143°43' | 40.3 | Sunnyside | 36°48' | 147°30' | 40* |
| French Island | 38°21' | 145°21' | 33.8 | Tanjil Bren | 37°50' | 146°12' | 68.5 |
| Gelantipy | 37°11' | 148°16' | 36.3 | Taralga | 34°24' | 149°49' | 30.5 |
| Gellibrand River | 38°32' | 143°32' | 42.7 | The Basin | 37°27' | 148°17' | 33* |
| Gorae | 38°14' | 141°33' | 33* | Thomson River, upper | 37°46' | 146°10' | 75.7 |
| Grampians | 37°30' | 142°15' | | Tolmie | 36°56' | 146°14' | 32.9 |
| Halls Gap | 37°08' | 142°32' | 36.0 | Toolangi | 37°33' | 145°29' | 50* |
| Hastings River | 31°30' | 152°30' | | Tyabb | 38°16' | 145°11' | 33* |
| Healesville | 37°40' | 145°31' | 40.2 | Victoria Range | 37°23' | 142°14' | |
| Heathmere | 38°14' | 141°38' | 32* | Waratah Bay | 38°48' | 146°06' | 40* |
| Hordern Vale | 38°46' | 143°31' | 44.4 | Warburton | 37°46' | 145°41' | 52.9 |
| Kangaroo Island | 35°40' | 137°20' | | Warrenbayne | 36°41' | 145°53' | 28.9 |
| Kallista | 37°52' | 145°32' | 54.8 | Warrnambool | 38°23' | 142°29' | 27.8 |
| Kaniva | 36°23' | 141°15' | 18.0 | Wilson's Promontory | 39°00' | 146°25' | 40.8 |
| Kew | 37°49' | 145°02' | 26* | Wombeyan Caves | 34°19' | 149°59' | 30* |
| Loch Valley | 37°47' | 146°01' | 56* | W Tree | 37°20' | 148°15' | 36* |
| Marysville | 37°31' | 145°45' | 54.8 | Wyong | 33°17' | 151°25' | 45.8 |
| Mooroopna | 36°24' | 145°22' | 19.2 | Yalmy River | 37°20' | 148°30' | 40* |
| Mount Dandenong | 37°49' | 145°21' | 57.9 | Yellingbo | 37°49' | 145°31' | 37* |

Note: Location of features such as mountains and streams is indicated at approximately centre of feature. Precise precipitation (inches, mean annual) is given when this has been available from the Bureau of Meteorology, Melbourne. Figures with asterisk are estimates based on data of adjacent towns.

the dry habitat assemblage of category 5 (see p. 22).

Points 1-3 indicate that the Wombeyan breccia deposit and the older Pyramids fraction represent the same small-mammal fauna, the fragmentation of which was probably associated with the extinction of large Pleistocene marsupials (see p. 17). Points 4-7 strongly suggest that the Wombeyan breccia deposit is about the same age as the final stages of accumulation of the older Pyramids fraction.

Broom (1896) assessed the Wombeyan breccia fauna as 'later Tertiary', and he believed it to contain extinct species and species ancestral to modern ones (Broom 1896a, 1896b). The present study indicates that the breccia deposit contains no wholly prehistoric species, and that its small mammals are in no cases very different from modern ones (see pp. 19-20).

The summaries, pages 17 to 20, show that in morphological characters the Wombeyan breccia fauna and the Pleistocene Pyramids fauna each exhibit about the same amount of variation in comparisons with the Holocene and modern faunas. In each of the first two assemblages the majority of species do not differ significantly from those of the Holocene or modern assemblages. Two species (*Potorous iridactylus* and *Pseudochirus peregrinus*) of the Wombeyan fauna, and two (*Perameles nasuta* and *Schoinobates volans*) of the Pleistocene Pyramids fauna, differ in tooth-size from corresponding Holocene or modern series. In proportions, variation from Holocene or modern series occur in the Wombeyan *Pseudomys oralis* (in incisive foramina) and two Pleistocene Pyramids species: *Antechinus swainsonii* (in ascending processes of dentary) and *Rattus fuscipes* (in zygomatic plate). Both the Wombeyan and the Pleistocene Pyramids *Mastacomys fuscus* have smaller teeth and longer zygomatic plate than in the Holocene and modern series from the Australian mainland. These analogies add weight to the suggestion that the Wombeyan breccia deposit and the older fraction of the Pyramids deposit are of similar antiquity.

For the Wombeyan breccia fauna Ride (1960) suggested 'an age somewhat later than the last pluvial period of the Pleistocene'. Lane and Richards (1967) state that this suggested age 'appears to be too recent to be consistent with the topography'.

It is probable that the Wombeyan deposit accumulated on the floor of a recess similar in character to the outer chamber of the Pyramids Cave, in a small cliff or steep limestone outcrop (see Plate 2). The 'two teeth . . . but no bones' of *Thylacinus*, and the *Wallabia* jawbones, found in

the Wombeyan deposit (Broom 1896c), and the absence of other remains of large animals, is remarkably similar to the occurrence of a single tooth of *Sarcophilus* and fragmentary macropodid remains in the Pyramids Cave (see p. 7). This indicates that the Wombeyan recess was used as a den by *Thylacinus* and that it took parts of its wallaby victims there. Owls would have needed a sheltered ledge in the recess, out of reach of terrestrial predators. There is now no evidence of a cliff line or of a steep slope at the actual site, but it is not unlikely that, being on an exposed hill, an outcrop containing a recess should have weathered to the present topography in several thousand years.

The available data suggest an age of the order of 10,000 years for the Wombeyan Caves breccia deposit.

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EXPLANATION OF PLATES

PLATE 1

Details of Pyramids Cave

- FIG. 1—Limestone cliff, eastern side of Pyramids hill, with openings of outer chamber and lower tunnel of cave indicated by arrows. The large shrub below the outer chamber is *Pittosporum undulatum* and the tree crown in the foreground is of *Eucalyptus melliodora*.
- FIG. 2—View from within outer chamber, with owls' landing platform low in foreground. The background is dry sclerophyll forest across Murrindal River.
- FIG. 3—Tooth (I_2) of *Sarcophilus laniarius* (arrowed), and sample pieces of fragmented bones presumably of prey of *Sarcophilus*; $\times 1.4$.

PLATE 2

Bone breccia site, Wombeyan Caves

- FIG. 1—The general environs: the 'cave' is between the figures. The tree on left is *Eucalyptus melliodora*.
- FIG. 2—The 'cave'. The breccia was obtained from the floor of the depression.

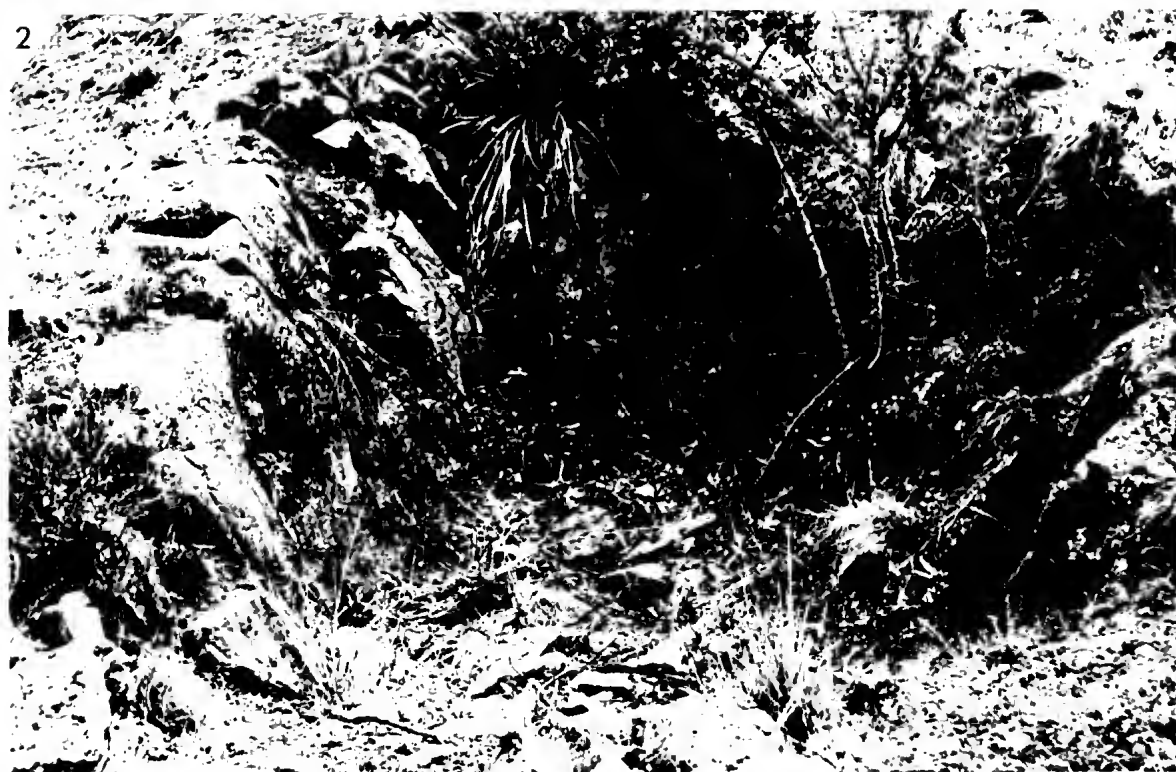
PLATE 3

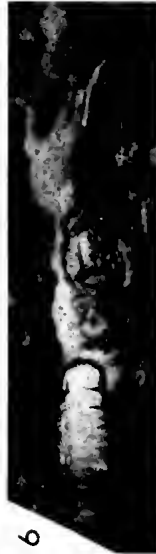
(All figures $\times 3$.)

Fossil specimens described by R. Broom, from Wombeyan Caves deposit

- FIG. 1—AM, F4198. Lectotype of *Perameles wombeyensis* Broom (= *Isodon macrourus*). Part dentary, with M_2 .
- FIG. 2—AM, F51878. Syntype of *Perameles wombeyensis* Broom, now excluded from diagnosis (= *Perameles nasuta*). Part dentary.
- FIG. 3—AM, F17501. Lectotype of *Palaeopetaurus elegans* Broom (= *Gymnobelideus leadbeateri*). Dentary with I , P_1 and M_1 .
- FIG. 4—AM, F51879. Syntype of *Perameles wombeyensis* Broom, now excluded from diagnosis (= *Perameles nasuta*). Part dentary, with C , P_1 , P_2 and unerupted P_3 .
- FIG. 5—AM, F4201. Lectotype of *Potorous tridactylus* var. *antiquus* Broom. Cranial piece, with P^1 (unerupted), dP^1 , M^1 and M^2 .
- FIG. 6—AM, F51880. Paratype of *Potorous tridactylus* var. *antiquus* Broom. Part dentary, with P_1 and bases of M_1 and M_2 .
- FIG. 7—AM, F4196. Lectotype of *Pseudocheirus antiquus* Broom (= *Pseudocheirus peregrinus*). Cranial piece, with P^3 , P^1 , incomplete M^1 , and M^2 .
- FIG. 8—AM, F51881. Syntype of *Pseudocheirus antiquus* Broom, now excluded from diagnosis (= *Schoinobates volans*). Part dentary, with diagnostic short angle (at lower right).
- FIG. 9—AM, F42322. Lectotype of *Macropus wombeyensis* Broom (= *Wallabia bicolor*). Part dentary, with P_1 (left), M_1 (right), and the intervening molars (M_1 , M_2 , M_3) somewhat broken away.







STUDIES OF VICTORIAN SEISMICITY

By ROBERT UNDERWOOD*

ABSTRACT: One hundred and seventy-five earthquakes have been instrumentally located in Victoria in the years 1958-1966 inclusive, and analysed for their geographic and time distribution, recurrence relationship, strain release, and direction of motion characteristics. Before November 1964, the strain release was logarithmically dependent on time, but after this date, it has been linear with time and there has been an unusual number of shocks of magnitude 4 or greater. A preliminary catalogue of earthquakes felt in Victoria confirms that the eastern half of the State has more earthquakes than the west, and that there are three principal active zones.

INTRODUCTION

Earthquakes are not uncommonly felt in Victoria, although the frequency and the size of shocks are minor compared to the active regions of the world. But, as recognized by Jaeger and Browne (1958), the very scarcity of shocks can be an advantage because it allows the pattern of seismicity to be observed rather clearly.

Although a number of authors have written about individual notable shocks or the distribution of shocks (Gregory 1903, 1910; Holmes 1933; Gaskin 1947; Burke-Gaffney 1951), it is only since 1958-1959 that better instrumental coverage has allowed detailed studies of Victorian earthquakes to be made.

The results of these studies, up to the end of 1966, are presented here. Consistent patterns of earthquake occurrence can be discerned even in this small time span. Continuing studies are required for verification, to observe new and more subtle patterns, and to provide data for the assessment of earthquake hazards in Victoria.

A CATALOGUE OF VICTORIAN EARTHQUAKES

A catalogue of over 280 earthquakes felt in Victoria since the commencement of settlement is presented in Table 1.

The primary source of most of these data is a collection of manuscript books and clipping books compiled by the staff of the Victorian Government Astronomer, and at present held by the Melbourne Observatory Group of the Bureau of Mineral Resources. Where possible, checks from other sources have been made, and details of the references are included in the Appendix to this

paper. The intensities have been assigned by the writer from the descriptions in the various sources, using the 1956 version Modified Mercalli Scale (Richter 1958).

The catalogue is not complete, for two main reasons. First, by no means all the printed sources have been examined. Diligent searching of the files of country newspapers, and of regional histories and their sources would no doubt reveal additional details of many shocks, and perhaps allow more confident assessment of intensities. Second, not all the earthquakes felt in Victoria would have been reported. From the commencement of settlement in 1835 until about 1883, only six shocks were reported, but the attention of the Government Astronomer seems first to have been drawn to seismology by the extraordinary swarm of earthquakes in 1883-1884 and 1885. A number of these were felt in coastal Victoria, and some in Melbourne. Lighthouse keepers at Gabo Island and elsewhere were recruited to report the tremors they felt, and all reports were carefully entered at the Observatory. Interest continued until about 1914, but declined after that until about 1932 when Holmes (1933) worked out an epicentre for the Mornington earthquake of that year. Since then, there has been a tendency to work from instrumental locations, and to collect felt reports only incidentally.

The number of catalogued earthquakes occurring in one degree 'squares' has been plotted in Fig. 1. As locations are only approximate, this coarse spacing is all that is warranted. When a report is from a locality near a boundary, a fractional count has been allotted to adjacent squares. The numbers ringed, and with an arrow, at east

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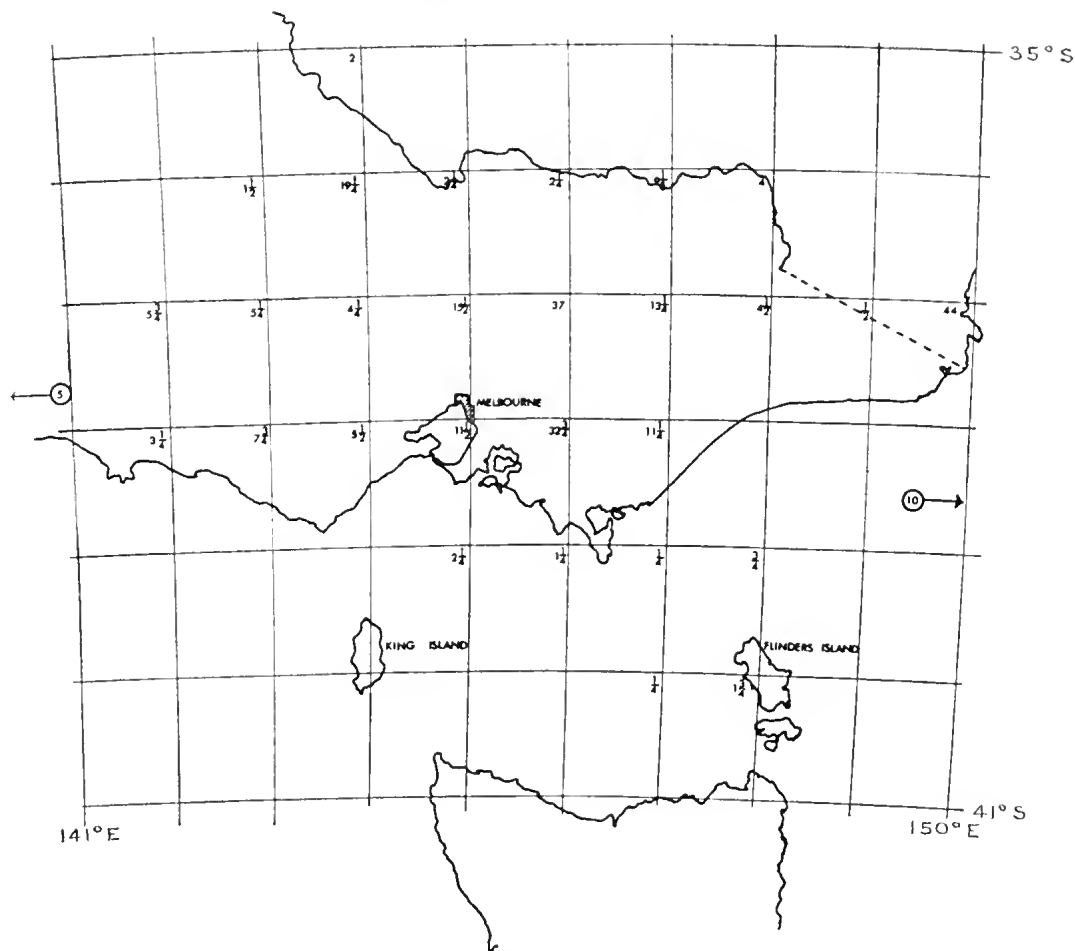


FIG. 1—Historical seismicity of Victoria. The numbers are the total of felt earthquakes from Table 1 which appear to have had their epicentres in the one degree 'squares'.

and west, show the number of shocks originating beyond the boundaries of the area, which were felt in Victoria. No attempt has been made to include Tasmanian earthquakes.

The most obvious feature of the diagram is the concentration of shocks round Melbourne, which is mainly but not entirely a reflection of the centralization of Victorian population. Next, it may be remarked that more shocks are reported from east of Melbourne than from the west. This is despite the scarcity of population in the Eastern Highlands and reflects the more active tectonic regime to the east. But there are persistent reports of earthquakes in the area centred on Wedderburn in the northwest. The large number of shocks reported from the far east of the State is due to the reports from the Gabo Island lightkeeper of the 1883 swarm.

The count omits a number of aftershocks, because it is usual to find only a general comment that there were 'several aftershocks' in the reports.

This omission probably helps to preserve the real pattern of seismicity.

EARTHQUAKES IN VICTORIA 1959-1966

In 1956-1958, new instruments well adapted to local earthquake recording were installed in Melbourne, Canberra, and in the Snowy Mountains. In the course of the routine work of the Geophysics Department of the Australian National University (ANU) using these stations, a number of earthquakes were located in Victoria, and to investigate the seismicity in more detail, the ANU commissioned new stations at Bogong in 1963, and at Buchan and Mt Tassie in 1964. The Bureau of Mineral Resources station at Melbourne was transferred to Toolangi in 1962 and a telemetered instrument came into operation at Melbourne in 1965. With these instruments, 175 shocks were located in Victoria in the seven years 1959 to 1966. These are listed in Table 2.

Table 1

VICTORIAN FELT EARTHQUAKES

| Year | Date | | Time GMT | Place, Intensity and Comments | Reference | Year | Date | | Time GMT | Place, Intensity and Comments | Reference |
|------|-------|-----|----------|--|---------------------------|------|-------|-----|----------|---|----------------|
| | Month | Day | | | | | Month | Day | | | |
| 1841 | 4 | | | Unknown, presume Melbourne | 4 | 1885 | 2 | 8 | 15 15 | Gabo Is. | 18 |
| 1847 | 4 | 28 | | Melbourne. "Panic very considerable" | 4 | 1885 | 2 | 21 | 10 00 | Gabo Is. | 6 |
| 1848 | 10 | 12 | | Earthquake at Melbourne | 3 | 1885 | 2 | 21 | 18 15 | Gabo Is. | 6 |
| 1855 | 9 | 16 | 17 12 | Melbourne, very extensive coastal area, estimated 140° - 143° E, 37° - 38° 30' S, i.e. Western Vic. | 4 | 1885 | 2 | 27 | 12 00 | Gabo Is. Bendoc II | 6, 18 |
| | | | | Double Shock? at Melbourne VI | | 1885 | 3 | 9 | 13 20 | Melbourne | 18 |
| 1868 | 8 | 30 | 10 35 | Felt Bairsdale, Deptford, Orbst | 1 | 1885 | 3 | 15 | 19 50 | Gabo Is. | 6, 18 |
| 1868 | 8 | 29 | 19 10 | Felt Bairsdale, Deptford, Orbst, Beechworth, Bright, Buckland and Albury | 1 | 1885 | 3 | 15 | 23 00 | Gabo Is. (Time may be incorrect) | 6, 18 |
| 1883 | 12 | 13 | | Tasmanian Swarm "noteworthy shock in this series" ... Biggs | 17 | 1885 | 3 | 16 | 9 45 | Gabo Is. (Time may be incorrect) | 18 |
| 1884 | 2 | 14 | 00 17 | Gabo Is. | 6 | 1885 | 3 | 20 | 23 25 | Gabo Is. Wilsons Prom. III - IV II - III | 6, 18 |
| 1884 | 2 | 17 | 6 10 | Gabo Is. | 6 | 1885 | 3 | 22 | 08 05 | Gabo Is. | 6, 18 |
| 1884 | 3 | 5 | 10 30 | Gabo Is. | 6 | 1885 | 3 | 22 | 18 30 | Gabo Is. | 6, 18 |
| 1884 | 3 | 18 | 12 20 | Gabo Is. | 6 | 1885 | 3 | 26 | 08 50 | Gabo Is. | 6, 18 |
| 1884 | 3 | 26 | 13 56 | Green Cape (N.S.W.) Severe | 6 | 1885 | 3 | 30 | 11 25 | Gabo Is. | 6, 18 |
| 1884 | 3 | 27 | 11 20 | Gabo Is. | 6 | 1885 | 5 | 4 | 11 00 | Gabo Is. | 6, 18 |
| 1884 | 6 | 9 | 10 20 | Gabo Is. | 6 | 1885 | 5 | 4 | 12 50 | Gabo Is. | 6 |
| 1884 | 6 | 17 | 10 36 | Green Cape (N.S.W.) Sharp | 6 | 1885 | 5 | 11 | 13 20 | Gabo Is. | 18 |
| 1884 | 7 | 13 | 4 40 | Gabo Is. Pt. Albert "Noteworthy shock in the Tasmanian series" ... Biggs | 17 | 1885 | 5 | 12 | 23 55 | Gabo Is. V Wilsons Prom. V Bairsdale, III - IV, Bruthen III, Sale - IV Warragul III - IV Melbourne - IV and at Lakes Entrance, Clydebank, Shellford, Foster III - IV Omeo III - IV Beechworth, also at Launceston VI "climax of the series" ... Biggs | 2, 4, 6, 7, 18 |
| 1884 | 8 | 3 | 2 40 | Gabo Is. | 6, 18 | 1885 | 5 | 27 | 07 20 | Gabo Is. | 17 |
| 1884 | 8 | 7 | 12 20 | Gabo Is. | 6, 18 | 1885 | 5 | 31 | 07 56 | Gabo Is. double shock III | 6, 18 |
| 1884 | 8 | 14 | 9 15 | Gabo Is. | 6 | 1885 | 5 | 31 | 12 45 | Gabo Is. III - IV | 6, 18 |
| 1884 | 9 | 16 | 11 50 | Gabo Is. | 6 | 1885 | 7 | 2 | 16 10 | Flinders IV Coves III - IV Cape Otway II Ballarat II Melbourne and Suburbs II - III Cape Schanck V, Tyabb, Hastings IV also Sunbury, Kilmore, Wilsons Prom., Lakes Entrance, Gabo Is. At Launceston II | 6, 7, 18 |
| 1884 | 9 | 19 | 10 50 | Gabo Is. Omeo Cape Schanck Lakes Entrance Wilsons Prom. Pt. Albert "noteworthy shock in the Tasmanian series" ... Biggs | 6, 4, 18, 17 | 1885 | 7 | 3 | 14 57 | Melbourne | 18 |
| 1885 | 1 | 9 | 17 35 | Mornington Cape Schanck IV - V | III II - III IV - V | 1885 | 7 | 16 | 22 15 | Gabo Is. | 6 |
| | | | | Berwick Prahman | I - II | 1885 | 8 | 1 | 05 00 | Gabo Is. | 6, 18 |
| 1885 | 1 | 30 | 15 05 | Gabo Is. | IV - V | 1885 | 8 | 1 | 15 18 | Gabo Is. | 6, 18 |

Table 1 (Contd)

| Year | Date | | Time GMT | Place, Intensity and Comments | Reference | Year | Date | | Time GMT | Place, Intensity and Comments | Reference |
|------|-------|-----|----------|--|-----------|------|-------|-----|----------|--|------------------------------|
| | Month | Day | | | | | Month | Day | | | |
| 1885 | 8 | 19 | 18 32 | Gabo Is. | III | 1892 | 1 | 26 | 16 55 | Aftershock of preceding | 4, 6 |
| 1885 | 9 | 11 | 09 25 | Gabo Is. III - IV, Oneco II, Wilsons Prom. II, Flinders II, Also Launceston, Gabo Is. | II | 1893 | 5 | 20 | 16 37 | Cliff Is. III | 6 |
| 1885 | 9 | 12 | 16 45 | Gabo Is. | II | 1893 | 7 | 21 | 18 15 | Oneco | 6 |
| 1885 | 10 | 7 | 23 56 | Bright IV, Beechworth III, Tallangatta II, Oneco III | III | 1893 | 7 | 22 | 15 35 | Castlemaine | 6 |
| 1885 | 11 | 1 | 04 52 | Gabo Is. | III | 1893 | 7 | 22 | 15 55 | Aftershock of preceding | 6 |
| 1886 | 1 | 3 | 22 56 | Gabo Is. | III | 1893 | 7 | 22 | 16 20 | Second aftershock of preceding | 6 |
| 1886 | 3 | 8 | 04 15 | Gabo Is. | III | 1893 | 10 | 9 | 12 43 | Seymour II | 6 |
| 1886 | 7 | 14 | 16 37 | Bright | IV | 1893 | 12 | 23 | 14 36 | Flinders IV - V, Cape Schanck II - III also at Mornington and Mount Martha Multiple shock? | 6 (reference 4 implies 1892) |
| 1886 | 8 | 2 | 11 15 | Gabo Is. also Eden (N.S.W.) | III | 1894 | 7 | 11 | 22 40 | Grant III | 6 |
| 1886 | 11 | 29 | 17 05 | Severe shock in N.S.W. Beechworth | II | 1894 | 11 | 22 | (03 15) | Gabo I II, Cape Everard III | 6 |
| 1886 | 12 | 2 | 08 43 | Cape Otway | III | 1894 | 12 | 10 | 08 20 | Oneco II | 6 |
| 1887 | 3 | 8 | 13 27 | Gabo Is. | III | 1895 | 5 | 8 | 10 50 | Cape Otway II - III | 6 |
| 1887 | 8 | 1 | 20 19 | Cape Otway III Apollo Bay III | II | 1896 | 2 | 1 | 16 30 | Cranbourne III - IV | 6 |
| 1887 | 11 | 9 | 16 33 | Gabo Is. also Hobart and Eastern Tasmania | III | 1896 | 3 | 28 | 07 30 | Gembrook II | 6 |
| 1889 | 1 | 10 | 06 47 | Undecipherable place name | I V | 1896 | 5 | 9 | 10 34 | Warragul II ? | 6 |
| 1889 | 7 | 29 | 08 40 | Gabo Is. | III | 1896 | 8 | 13 | 11 30 | Drouin III - IV also felt at Longwary, Bunyip, and Neerim South | 6 |
| 1889 | 10 | 27 | 10 16 | Oneco | 18 | 1896 | 5 | 30 | ? | Yinnar II ? | 6 |
| 1890 | 10 | 17 | 21 20 | Ardmore | 18 | 1896 | 8 | 13 | 11 30 | Oneco II also at Harriettville, St. Bernard's and Alexandra | 6 |
| 1891 | 6 | 7 | 04 24 | Rosebud V, Sorrento IV Melbourne and Southern Suburbs II - IV also felt at Queenscliff, Myrion near Ballarat and Frankston | 4, 6, 18 | 1897 | 3 | 29 | 11 55 | Kerang, Western Victoria V also at Wandella Lakes | 6 |
| 1891 | 6 | 8 | 04 08 | Melbourne | 18 | 1897 | 5 | 10 | 05 30 | The Kingston S.E. earthquake. Recorded Melb. at 3.35 at Kingston; VIII - IX | 4, 6 |
| 1891 | 7 | 5 | 10 20 | Kariot III (thunderstorm ?) | 6, 18 | 1897 | 6 | 4 | | Harrow (Western Vic) | 19 |
| 1891 | 7 | 9 | 05 50 | Wahalla III felt from Toongabbie to Woods Point | 6, 18 | 1897 | 9 | 26 | 19 00 | Oneco | 6, 19 |
| 1891 | 7 | 9 | 09 40 | aftershock of preceding Wahalla | 6, 18 | 1898 | 1 | 29 | 11 20 | Yea II - III | 6 |
| 1891 | 7 | 30 | 17 40 | North Melbourne | 6 | 1898 | 2 | 5 | 01 40 | Warburton IV | 6 |
| 1891 | 10 | 20 | 06 20 | Grantville | III ? | 1898 | 9 | 6 | 04 15 | Alexandra V, Yea IV, also felt at Tallarook | 6 |
| 1892 | 2 | 26 | 16 50 | Severe shock felt throughout Tasmania. In Victoria : Gabo I IV - V, Wilsons Prom. IV, Foster III - IV, Oneco II, and at Welshpool, Cape Everard, Grant and Little Yarra. Also felt at Genoa (NSW). Location by Illegben about 41.4°S 153.8°E | 4, 6, 16 | 1898 | 11 | 22 | 01 40 | Mansfield IV | 6 |
| | | | | | | 1898 | 12 | 20 | (05 35) | Goornong V | 6 |
| | | | | | | 1899 | 1 | 31 | | Canterbury II recorded by the Melbourne Observatory | 6 |

Table 1 (Contd)

Table 1 (Contd)

| Date | | | Time | | | Place, Intensity and Comments | | | Reference | | | | |
|------|-------|------|---------|------|-------|-------------------------------|-----|---|----------------|-------|-----|-----|-----------|
| Year | Month | Day | GMT | Year | Month | Day | GMT | Place, Intensity and Comments | Year | Month | Day | GMT | Reference |
| 1903 | 8 | 4 | 09 32 | | | | | Foster Leongatha | II - III II | | | | 6, 21 |
| 1903 | 8 | 14 | 10 30 | | | | | Port Fairy, Hamilton (Western Vic.) | | | | | 6 |
| 1903 | 8 | (18) | 12 55 | | | | | Hamilton (Western Vic.) date is in doubt, may be 17th or 19th | III | | | | 6, 21 |
| 1903 | 9 | 4 | 10 45 | | | | | Dunolly (Western Vic.) | IV - V IV | | | | 6, 21 |
| 1903 | 9 | 4 | 15 10 | | | | | Yea | | | | | 6 |
| 1903 | 9 | 23 | 11 20 | | | | | Mansfield | II | | | | 6, 21 |
| 1904 | 4 | 9 | 22 05 | | | | | Bright Myrtleford | V IV | | | | |
| | | | | | | | | Harrietville | III - IV | | | | |
| | | | | | | | | Albury District | III - IV | | | | |
| | | | | | | | | Dargo | III - IV | | | | |
| | | | | | | | | Ensay | III - IV | | | | 6 |
| 1904 | 4 | 17 | 16 00 | | | | | Leongatha | II | | | | 6 |
| 1904 | 5 | 27 | 13 25 | | | | | Leongatha Outtrim | IV - V IV | | | | |
| | | | | | | | | Meenyan | | | | | 6 |
| 1904 | 7 | 9 | 09 26 | | | | | Melbourne and Southern Suburbs, and Dandenong Ranges | III - V | | | | |
| | | | | | | | | Recorded on Melbourne Observatory Seismograph | | | | | 6 |
| 1904 | 7 | 13 | 19 00 | | | | | Aftershock of previous? | | | | | |
| | | | | | | | | Southern Melbourne Suburbs | III - IV | | | | 6 |
| 1904 | 9 | 22 | 11 45 | | | | | Korumburra | V | | | | 6 |
| 1904 | 11 | 6 | Morning | | | | | Bulu Bulu | | | | | 6 |
| 1905 | 1 | 27 | 16 00 | | | | | Traralgon | IV | | | | |
| | | | | | | | | Walhalla | III | | | | |
| | | | | | | | | Moe | II | | | | 6 |
| 1905 | 5 | 22 | 21 30 | | | | | Hamilton (Western Vic.) | II | | | | 6 |
| 1905 | 6 | 10 | 14 15 | | | | | Portland and Cape Nelson (Western Vic.) | II | | | | 6 |
| 1905 | 6 | 27 | 10 30 | | | | | Ensay Swifts Creek | IV - V | | | | |
| | | | | | | | | Omoo | | | | | 6 |
| | | | | | | | | Aftershocks | | | | | |
| 1905 | 7 | 1 | Evening | | | | | Yea | | | | | 6 |
| 1905 | 7 | 12 | 14 20 | | | | | Portland | | | | | |
| 1905 | 7 | 17 | | | | | | Aftershock in Oneco district | | | | | 6 |
| 1905 | 7 | 27 | | | | | | Aftershock in Oneco district | | | | | 6 |
| 1905 | 8 | 20 | 16 00 | | | | | Aftershock at Ensay | | | | | 6 |
| 1905 | 8 | 20 | 17 45 | | | | | Aftershock at Ensay | | | | | |
| 1905 | 8 | 21 | 16 00 | | | | | Western Victoria or South Australia Intensity appears to be distributed irregularly Hamilton VI Natimuk and Echuca V - VII Ballarat VI - VII Rapunyip, Servicetown ... "Severe" | | | | | 6, 7 |

Table 1 (Contd)

| Year | Date Month | Day | Time GMT | Place, Intensity and Comments | Reference | Year | Date Month | Day | Time GMT | Place, Intensity and Comments | Reference |
|------|---------------|-----|-------------|--|-----------|------|---------------|-----|-------------|--|-----------|
| 1907 | 6 | 8 | 16 05 | Cape Otway | 6 | 1910 | 12 | 27 | 11 15 | Korongvale Inglewood III + | 6 |
| 1907 | 6 | 25 | 18 04 | Anglesca | 5, 10 | 1911 | 1 | 5 | 17 55 | Felt South Yarra IV - V, St. Kilda and at Dandenong, but not recorded by the Mine at Melbourne Observatory | 6 |
| 1907 | 8 | 6 | 00 54 | Warragul Yarragon Drouin, Bairnsdale Possibly several aftershocks | 5, 6 | 1911 | 3 | 7 | 16 10 | Berwick | 5, 6 |
| 1907 | 10 | 4 | 09 30 | Yea Seymour also at Broadford, Naganbie and Windsor | 5, 6 | 1911 | 3 | 14 | 23 10 | Katamatite | 6 |
| 1907 | 12 | 11 | 08 05 | Ensay | 6 | 1911 | 6 | 11 | 14 35 | Portarlington IV - V | 6 |
| 1908 | 3 | 22 | 01 00 | Bealiba, Dunolly (Western Vic.) | 5, 6 | 1911 | 8 | 26 | 09 15 | Bainorsal | 6 |
| 1908 | 4 | 13 | 02 00 | Hamilton | 6 | 1911 | 10 | 27 | 02 50 | Bealiba (Western Vic.) IV | 6 |
| 1908 | 5 | 6 | 16 00 | Jameson | 6 | 1912 | 5 | 5 | 09 00 | Maryborough IV | 6 |
| 1908 | 6 | 9 | 19 30 | Berwick Pakenham | 6 | 1912 | 8 | 11 | 07 15 | Bealiba IV + Goldsborough, Eddington, St. Annard, Dunolly, Tarnagulla | 6 |
| 1908 | 6 | 15 | 14 00 | Korumburra .. distinct | 6 | 1913 | 3 | 2 | 17 45 | Beechworth IV - V Benalla IV Shepparton IV Numurkah IV Wangaratta III - IV and Dookie, Tungkawah | 6 |
| 1908 | 7 | 15 | 19 00 | Tooradin III - IV | 6 | 1913 | 11 | 26 | 09 50 | Lilydale III - IV and Warburton, Genbrook, Beaconsfield Upper | 6 |
| 1908 | 7 | 23 | 04 00 | Foster II Pakenham IV Berwick Fern Tree Gully | 6 | 1913 | 11 | 27 | 04 00 | Cheltenham, Port Melbourne, Mentone, Black Rock | 6 |
| 1908 | 10 | 19 | 11 00 | Lilydale .. distinct | 6 | 1914 | 8 | 17 | 23 35 | Bunyip IV Drouin IV Warragul IV Mirboo North IV Toolangi III and Genbrook, Korumburra, Pakenham | 6 |
| 1908 | 10 | 23 | 17 50 | Wedderburn IV - V ".... very severe" | 6 | 1914 | 9 | 5 | 11 00 | Fish Creek | 6 |
| 1908 | 10 | 23 | 18 50 | Wedderburn ".... medium" Aftershock | 6 | 1915 | 2 | 27 | 12 15 | Rosedale IV | 6 |
| 1908 | 10 | 23 | 21 15 | Wedderburn ".... light" aftershock | 6 | 1915 | 5 | 24 | 08 00 | Rosedale ... Severe | 6 |
| 1908 | 10 | 27 | 09 30 | Drouin, Langvally | 6 | 1922 | 2 | 28 | 15 00 | Severe at King Is., felt Melbourne, Lorne and Warragul Located by Melbourne staff from Melbourne seismogram, Toolangi magnetogram, and felt reports, at about 39° S 145° E | 8 |
| 1908 | 11 | 20 | 04 50 | Gabo Is. IV | 6 | 1922 | 4 | 10 | 10 45 | Local 40° S 147.5° E by Burke Gaffney Located 39° 20' S 144° 20' E by Melbourne Observatory staff in the same was as preceding King Is. VI | 8 |
| 1908 | 12 | 19 | 14 24 | Gastlemaine | 6 | 1922 | 11 | 20 | 10 30 | Tallangatta | 8 |
| 1909 | 3 | 5 | 02 10 | Alfredton | 12 | 1922 | 12 | 9 | 05 20 | Warrnambool | 8 |
| 1909 | 3 | 29 | 17 57 | Flinders | 12 | 1929 | 12 | 28 | 01 22 | Located at 40° S 147.5° E by Burke Gaffney | 7 |
| 1909 | 5 | 31 | 16 00 | Casterton IV - V | 5, 12 | 1931 | 3 | 13 | 21 11 | Felt Melbourne suburbs, Geelong and also on N.W. coast of Tasmania Melbourne: e 21:11:04 | 15 |
| 1909 | 8 | 4 | 11 05 | Pakenham | 6 | | | | | | |
| 1909 | 11 | 15 | 03 55 | Bairnsdale IV Buchan II Bruthen | 6 | | | | | | |
| 1910 | 3 | 18 | 21 15 | Bunyip IV Moe, Warragul, Drouin, Yarragon | 5, 6 | | | | | | |
| 1910 | 10 | 24 | 08 30 | Drouin IV Lang Lang | 5, 6 | | | | | | |
| 1910 | 10 | 24 | 17 00 | Bunyip | 5, 6 | | | | | | |

Table 1 (Contd.)

| Year | Date Month | Day | Time GMT | Place, Intensity and Comments | Reference | Year | Date Month | Day | Time GMT | Place, Intensity and Comments | Reference |
|------|---------------|-----|-------------|--|-----------|------|---------------|-----|-------------|---|-----------|
| 1932 | 2 | 14 | 15 27 | Felt Flinders Island and at Fligal (Tas) Melbourne: i 15:27:38 | 15 | 1939 | 11 | 29 | 15 03 | Felt S. Eastern suburbs, Cowes and Worthing Melbourne: i 15:03:07 | 11 |
| 1932 | 9 | 2 | 18 22 | Mornington earthquake located by Holmes 38 15 S 145 E. The month given in Burke-Gaffney appears to be in error | | 1939 | 12 | 15 | 00 25 | Felt Auburn Melbourne: i 00:25:05 | 11 |
| 1932 | 9 | 2 | 20 35 | After shock of preceding Melbourne Mline Shaw: i 20:35:28 | 7, 8, 9 | 1940 | 1 | 31 | 18 54 | Felt S. E. suburbs Melbourne: i 18:54:08 | 11 |
| 1932 | 9 | 2 | 20 41 | After shock of preceding Melbourne Mline Shaw: i 20:41:07 | 11 | 1941 | 11 | 4 | 02 33 | Melbourne: i 02:33:15 | 15 |
| 1932 | 9 | 21 | 05 00 | Benalla. Earthquake swarm with intensity up to VI at Benalla, but not felt even so close as Winton (6 miles) Glenrowan (14 miles) or Violet Town (16 miles). Activity continued for some months. | 11 | 1942 | 8 | 1 | 12 39 | Felt in N. E. Victoria. Melbourne: i 12:39:11 | 15 |
| 1932 | 10 | 9 | 16 30 | Boort (Western Victoria) | 8 | 1944 | 11 | 2 | 14 05 | Caribbean Range Earthquake. Felt throughout Central Victoria. Location of mesoseismal area about 37.5°S 146°E (Gaskin) Melbourne: i 14:05:42 | 14, 15 |
| 1932 | 10 | 9 | 20 10 | Boort Aftershock | 8, 11 | 1945 | 5 | 14 | 03 03 | May be regional Melbourne: P 03:03:45 | 15 |
| 1932 | 10 | 9 | 23 00 | Boort Aftershock | 8 | 1946 | 8 | 15 | 14 37 | Felt Brighton, Caulfield, Point Ormond and Glen Iris. Melbourne: i 14:37:39 | 15 |
| 1932 | 10 | 18 | 21 40 | Boort VI | 8 | 1946 | 9 | 14 | 19 49 | S-1923 sec. Located 40°S 141°E by Burke- Gaffney. Melbourne: P 19:49:54 | 7, 15 |
| 1932 | 10 | 20 | 00 30 | | 8, 11 | 1947 | 1 | 5 | 07 00 | Barwood faint tremor. No record at Melbourne at the time | 15 |
| 1932 | 10 | 26 | 03 08 | Felt Boort, Castlemaine, Pyramid Hill, Bridgewater. Melbourne: i 03:08:04 | 11 | 1947 | 6 | 9 | 07 03 | Colac. Melbourne: i 07:03:42 | 15 |
| 1932 | 12 | 23 | 14 16 | May have been several shocks in this series Belgrave V - VI also felt at Berwick, Tooradin, Pakenham and Nar Nar Goon | 8, 11 | 1947 | 11 | 16 | 09 19 | Probably local shock. Melbourne: i 09:19:19 | 15 |
| 1935 | 6 | 18 | 17 47 | Melbourne: i 14:16:44 | 8, 11 | 1948 | 1 | 16 | 11 20 | Probable local shock. Melbourne: i 11:20:14 | 15 |
| 1937 | 6 | 17 | 19 54 | Felt N. E. suburbs of Melbourne Melbourne: i 17:47:29 | 11 | 1948 | 3 | 13 | 17 47 | Probable local shock. Melbourne: i 17:47:48 | 15 |
| 1938 | 3 | 24 | 20 04 | Felt at Ferntree Gully, Berwick and eastern suburbs Melbourne: i 19:54:57 | 11 | 1948 | 4 | 28 | 19 41 | Probable local shock. Melbourne: i 19:41:06 | 15 |
| 1938 | 5 | 22 | 21 41 | Local shock or explosion, recorded on Melbourne seismograph. No felt reports. Melbourne: i 21:41:15 | 11 | 1949 | 3 | 19 | 18 39 | Felt Malvern and Black Rock. Melbourne: i 01:00:02 | 15 |
| 1939 | 3 | 31 | 07 35 | Felt in suburbs Melbourne: i 07:35:21 | 11 | 1949 | 3 | 19 | 18 39 | Probable local shock. Melbourne: i 18:39:22 | 15 |
| 1939 | 4 | 5 | 12 39 | Felt Geelong and Portarlington. Lorne, suburbs of Melbourne, Kilmore and Ballarat. Recorded on Melbourne seismograph, date appears in error in Burke-Gaffney | 11, 7 | 1957 | 2 | 14 | 02 29 | Felt Clayton, Doncaster, Mentone Melbourne: i 02:29:22 | 22 |
| 1939 | 10 | 29 | 13 24 | Felt Armadale, Camberwell, and Cowes, Dalyton Melbourne: i 13:24:22 | 22 | 1957 | 4 | 6 | 08 35 | Felt Qumlatook, Kerang, Dumosa. Melbourne: i 08:35:22. Located by Melbourne Observatory at 143°19'E, 35°53'S | 22 |
| | | | | | | 1957 | 8 | 16 | 06 03 | Felt 7 miles East of Nagambie After shock | 22 |
| | | | | | | 1957 | 8 | 16 | 19 16 | " | 22 |
| | | | | | | 1957 | 8 | 18 | 20 19 | " | 22 |
| | | | | | | 1957 | 8 | 21 | 12 10 | " | 22 |
| | | | | | | 1957 | 8 | 21 | 12 19 | " | 22 |
| | | | | | | 1957 | 8 | 31 | 14 56 | Felt Doveton, Hurkaway and Dandenong | 22 |
| | | | | | | 1957 | 10 | 19 | 10 49 | Foster, Fish Creek, Walkerville | 22 |
| | | | | | | 1959 | 1 | 19 | 08 52 | Felt southern and Eastern suburbs of Melbourne III - IV | 22 |
| | | | | | | 1959 | 3 | 15 | 12 38 | Felt Merton | 22 |
| | | | | | | 1959 | 3 | 25 | 12 30 | Felt Hughesdale | 22 |
| | | | | | | 1959 | 6 | 1 | 23 35 | Seaford | 22 |
| | | | | | | 1959 | 6 | 1 | 03 00 | Seaford and Carrum | 22 |

In this table, epicentres are expressed to the third decimal place, and origin times to 0.1 sec, all with standard errors (Hald 1952), when a solution has been made using a computer programme developed from Flinn (1960). The focal depth is normally the least reliably determined parameter, and depths estimates that have failed to converge are bracketed. Fortunately, the epicentral location is relatively insensitive to inaccuracies in the depth estimate.

Next most reliable are the locations made graphically on a scale of 1:1 million. These are expressed in degrees and minutes, with origin times to the nearest second. It has not been possible to determine focal depths, nor error estimates, for these locations.

In all cases, a comment is given showing the location of the nearest named feature on the Geographic Series maps. Reliability is further distinguished by the qualification 'probably' for shocks that could be located to only a few tens of kilometres, and 'possibly' where gross errors may exist: for example, if only two stations recorded recognizable signals, and a choice of intersections had to be made.

All locations were made using the same simple model of the Earth's crust and mantle, consisting of 37 km of material with P velocity 6.01 km/sec and S velocity 3.61 km/sec, over a mantle of P velocity 8.16 km/sec. Recent work, however, indicates that there are probably two main crustal layers, that the Mohorovičić discontinuity dips to the south from the Snowy Mountains, and that the mantle P velocity is below 8 km/sec (Underwood 1967, Chap. 6). Many of the tabulated locations, especially those in Bass Strait and along the south coast might therefore be biased perhaps as much as 10 km south of their true positions. Relocation, however, will have to be deferred until the velocities and structures under Victoria are better known.

'Magnitudes' have been calculated from the maximum double amplitude on the vertical short period seismograph records. A divisor expressing the ratio of the velocity magnification of each instrument in the period range $\frac{1}{2}$ to 1 sec to that of a Wood-Anderson instrument in standard adjustment has been applied to reduce amplitudes to 'equivalent Wood-Anderson trace amplitudes', which have then been reduced to magnitudes using the nomogram devised by Nordquist (Gutenberg and Richter 1942). The divisors are:

| | | | |
|----------------|----|---------------------|----|
| Canberra | 18 | Buchan | 5 |
| Snowy Stations | 40 | Mt Tassie low gain | 2 |
| Bogong Mk I | 4 | Mt Tassie high gain | 40 |
| Bogong Mk II | 40 | | |

Although this method does not take account of the possibility of variation in the ratio of horizontal to vertical movement, it not only gives internally consistent results, but also produces numbers consistent with the local magnitude (M_L) scale of Richter (1935), as comparison between Wood-Anderson and Benioff short period vertical records from the same station have shown (Cleary 1963).

Where the magnitude is bracketed, some doubt as to the correct value exists. The value adopted is conservative, and no large shocks are involved.

It is interesting that some earthquakes were large enough, and therefore recorded sufficiently widely, to be located during the routine work of the United States Coast and Geodetic Survey (now known as the National Ocean Survey). Seven of these locations, all in Bass Strait where locations using local stations suffer from inaccuracy due to poor network geometry and velocity bias, have been adopted in the table. These are marked USCGS. Depths are restricted where an (R) appears after the value. The magnitudes tabulated, however, are local-scale magnitudes as described above, not the body wave magnitude (m) quoted by the USCGS, which is generally smaller in this range by more than half a unit.

These epicentres have been plotted on a map in Fig. 2. The number is the magnitude, as follows:

| | | | |
|---|---|---------------|---|
| x | event inadequately located, or no magnitude scaled. | | |
| 1 | magnitude 1.0 to 1.9 inclusive. | | |
| 2 | " | 2.0 to 2.9 | " |
| 3 | " | 3.0 to 3.9 | " |
| 4 | " | 4.0 to 4.9 | " |
| 5 | " | 5.0 and over. | |

A circle indicates a swarm or aftershock sequence, the number being the magnitude of the largest shock of the series.

Several features displayed by this map are worthy of notice:

(1) All the earthquakes appear to be in the Earth's crust, none in the mantle.

(2) The concentration of shocks around Corner Inlet and the South Gippsland Hills is well known. Aftershock sequences are often observed in this area.

(3) There is a preponderance of earthquakes in the eastern half of the State rather than in the west. All the recording stations are east of Melbourne so that the identification and location of a shock is favoured in the east. But the same effect occurring in the historical data and shown in Fig. 1 indicates that this is a real difference, with tectonic significance.

Table 2
Earthquakes located in Victoria 1959-1966

| Date | Time GMT | SE (sec) | Lat. | SE (km) | Long | SE (km) | Depth | SE (km) | Mag | Comments |
|-------------|-------------|-------------|--------|------------|---------|------------|--------------------|------------|-------|-----------------------------------|
| <u>1959</u> | | | | | | | | | | |
| 28 Apr | 08:09:00 | | | | | | | | 3.3 | 45 Miles South of Cape Everard |
| 23 Jul | 16:41:00 | 36°19' | | | 146°33' | | 0 | | 3.0 | Near Eldorado, N.E. Vic. |
| <u>1960</u> | | | | | | | | | | |
| 28 Jan | 23:36:56 | | 36°75' | | 147.1 | | 15 | | (4) | Bright (refer Cleary, 1963) |
| 28 Apr | 04:47:58.2 | 10.9 | 37°768 | 71 | 148.440 | 68 | depth intermediate | | 3 | 5 km south of Orbst |
| 3 May | 02:20:04 | | | | | | | | 3-3/4 | South Gippsland near Corner Inlet |
| 4 May | 00:42:50 | | | | | | | | 3 | Womangatta valley |
| 18 May | 02:55:16.8 | 56 | 37°334 | 339 | 147.841 | 698 | | | 2-1/2 | Near Mt. Ellery, E. Gippsland |
| 25 May | 09:32:28 | | | | | | | | 2-3/4 | Eastern Bass Strait |
| 29 May | 02:41:03.1 | 0.4 | 36°515 | | 147.428 | 1.8 | (-18) | 3.0 | 2-1/2 | Mitta Mitta |
| 1 June | 05:18:47.6 | 3.3 | 36°763 | 23.7 | 145.354 | 26.6 | 12.4 | 13.5 | 3-1/2 | Nagambie |
| 4 June | 12:43:10 | | 36° | | 146°42' | | | | 4-1/4 | South of Cape Otway |
| 21 June | 07:09:28 | | | | | | | | 2-1/4 | Murray valley west of Albury. |
| 20 Oct | 20:22:04.6 | 3.2 | 38°563 | 38.6 | 146.449 | 13.3 | 8.4 | 24 | 4 | Corner Inlet |
| 21 Oct | 14:47:57.0 | 35 | 38°895 | 310 | 146.496 | 76 | | | 3-9 | Wilsons Promontory |
| 4 Nov | 17:55:27 | | 37° | | 148°18' | | | | 2 | West of Mount Bulla, E. Gippsland |
| 5 Nov | 06:31:15.7 | 1.0 | 37°121 | 5.5 | 148.302 | 4.8 | (-14) | 47 | 2-1/2 | South of the Delegate River |
| 8 Nov | 13:29:28 | | 37°06' | | 148°08' | | | | 1-3/4 | N.W. of Mt. Statham, E. Gippsland |
| 20 Nov | 21:09:52.7 | 0.3 | 36°845 | 5.2 | 147.304 | 3.0 | (-1.3) | 2.6 | 2-1/4 | N.W. of Orneo |
| 23 Dec | 09:39:52.6 | 3.7 | 37°754 | 21.7 | 148.281 | 15.6 | 22.1 | 9.8 | 3 | Between Orbst and Nowa Nowa |
| 24 Dec | 16:42:08.5 | | 39° | | 143°30' | | 77 | | 5-1/4 | Cape Otway (U. S. C. G. S.) |
| <u>1961</u> | | | | | | | | | | |
| 22 Jan | 14:43:55 | | 39°30' | | 155°30' | | | | 4 | South Tasman Sea |
| 22 Jan | 18:39:45 | | 40° | | 155°30' | | | | 4 | " |
| 3 Feb | 14:37:45 | | 40° | | 148°30' | | | | 4 | " |
| 28 Mar | 04:02:08.9 | 3.7 | 37°620 | 15.7 | 148.094 | 24.8 | (-23) | 22.3 | 2-1/4 | Near Flinders Island |
| 10 Apr | 14:10:32.6 | 4.3 | 37°142 | 18.7 | 144.051 | 4.6 | (-5.6) | 34.6 | 4 | South of Malden. Felt: Malden |
| 11 Apr | 00:35:23.4 | 13.1 | 38°281 | 93 | 146.468 | 25.7 | (46) | 57 | 4 | South Gippsland Hills. |
| 13 Apr | 06:40:10 | | 36°15' | | 146°30' | | | | 2-1/2 | Vicinity Ovens River |
| 28 Apr | 23:09:50 | 12.7 | 38°567 | 21.5 | 144.531 | 14.1 | 5.3 | 110 | 2-1/4 | Probably S.W. of Mitchell River |
| 1 Jun | 09:53:07.7 | | 38°18' | | 144°06' | | 29 | | 4-1/4 | Northern Bass Basin |
| 1 Jun | 13:19:51 | | 37°24' | | 149°06' | | | | 2 | Bass Strait (U. S. C. G. S.) |
| 12 Aug | 21:01:58 | | 37°36' | | 148°12' | | | | 2-1/2 | S.W. of Mt. Kaye, E. Gippsland |
| 14 Aug | 19:59:43 | | | | | | | | 2-1/2 | Near Nowa Nowa |
| 12 Sep | 07:13:09.4 | 4.4 | 40°686 | 29.2 | 156.609 | 183 | (576) | 170 | 4-1/4 | South Tasman Sea |
| 15 Sep | 05:09:40.1 | 26.8 | 37°534 | 26.8 | 147.294 | 15.6 | 22.0 | 10.5 | 3-1/2 | Near Tabberaberra |
| 9 Oct | 23:43:14.3 | 2.0 | 37°534 | 155.3 | 145.882 | 45.4 | (49.4) | 76 | 4 | Tarwin Meadows |
| 9 Oct | 23:59:23.4 | 21.6 | 39°211 | | | | | | 3-1/2 | Aftershock |
| 10 Oct | 00:03:00.1 | | | | | | | | 3-1/2 | " |
| 10 Oct | 00:06:15 | | | | | | | | 2-3/4 | " |
| 10 Oct | 00:08:00 | | | | | | | | 2-3/4 | " |
| 10 Oct | 06:45:31 | | | | | | | | 3-1/2 | " |
| 10 Oct | 13:36:08 | | | | | | | | 4 | " |
| 10 Oct | 20:50:44 | | | | | | | | 2-3/4 | " |
| 12 Oct | 22:48:01 | | | | | | | | 3-1/2 | " |
| 13 Oct | 06:47:09 | | | | | | | | 2-3/4 | " |
| 19 Oct | 15:23:49 | | | | | | | | 3 | Probably Aftershock |
| 22 Nov | 21:55:16.8 | 19.7 | 30°017 | 84.4 | 146.028 | 74.9 | (-69) | 129 | 3-1/2 | Probably near Walballa |

Table 2 (Contd)

| Date | Time GMT | SE (sec) | Lat. | SE (km) | Long | SE (km) | Depth (km) | SE (km) | Mag | Comments |
|-------------|------------|----------|---------|---------|----------|---------|------------|---------|---------|--|
| <u>1962</u> | | | | | | | | | | |
| 10 Jan | 05:40:31 | | 38° 30' | | 146° 30' | | | | 3-3/4 | Corner Inlet |
| 10 Jan | 06:12:17 | | | | | | | | 3-3/4 | Aftershock |
| 10 Jan | 19:21:10 | | | | | | | | 1-3/4 | Probably near Bonang |
| 11 Jan | 09:10:49.4 | 21.9 | 37.804 | 137.3 | 148.811 | 352.3 | (4296) | 17 | 2-1/2 | Cape Conran |
| 7 Mar | 14:17:14 | | | | | | | | | Probably double shock in the vicinity of lake Wellington |
| 7 Mar | 14:17:27 | | | | | | | | | East of Walhalla |
| 27 Mar | 17:54:22.2 | 0.2 | 37.920 | 2.6 | 146.547 | 1.1 | 5.9 | 0.8 | 3-3/4 | East of Walhalla |
| 11 Apr | 18:28:58 | | 38° 54' | | 146° 20' | | | | 3-1/2 | Wilson's Promontory |
| 27 May | 11:34:28.9 | 17.2 | 38.582 | 22.4 | 146.385 | 61.1 | (-32) | 176 | 3-1/2 | Wongip |
| 27 May | 11:49:07.8 | | | | | | | | 3 | Aftershock |
| 22 June | 06:12:03 | | | | | | | | | Vicinity of Foster |
| 5 Jul | 13:00:02.7 | 0.5 | 37.173 | 2.1 | 148.018 | 5.8 | (-4.5) | 2.4 | 2-1/2 | West of Mt. Stratham |
| 30 Jul | 11:43:11 | | | | | | | | 1-1/2 | Vicinity of Deddick River |
| 30 Jul | 11:44:54 | | | | | | | | 1-3/4 | " " |
| 30 Jul | 11:47:25 | | | | | | | | 1.6 | " " |
| 30 Jul | 11:50:59 | | | | | | | | 1.8 | " " |
| 8 Aug | 22:46:06 | | | | | | | | | Indeterminate, possibly Northern Goulburn Valley |
| 17 Aug | 03:45:12 | | 38° 00' | | 148° 12' | | | | | Off coast south of Orbost |
| 17 Aug | 03:45:18 | | | | | | | | | Probably Aftershock |
| 20 Aug | 06:07:27 | | | | | | | | 3 | Possibly in vicinity of Maffra |
| 26 Sep | 09:02:57.3 | 1.3 | 36.497 | 11.8 | 147.146 | 8.6 | 16.3 | 10.5 | 2-3/4 | Esisdale - Upper Gundowring |
| 13 Oct | 07:59:44 | | | | | | | | 1-3/4 | Probably south of Bonang |
| 20 Nov | 12:15:28 | | | | | | | | 3-1/2 | Near Foster |
| 15 Dec | 21:41:32 | | | | | | | | 3-1/4 | Corner Inlet |
| 15 Dec | 21:59:55 | | | | | | | | | Aftershock |
| 26 Dec | 10:51:27.6 | 2.4 | 37.568 | 27.7 | 146.888 | 12.4 | (-6) | 12 | 3-1/4 | Mount Wellington |
| 31 Dec | 19:10:25.6 | 2.6 | 36.304 | 20.6 | 146.405 | 14.0 | (-23) | 17 | 2-3/4 | Wangaratta |
| <u>1963</u> | | | | | | | | | | |
| 14 Jan | 06:31:54.1 | 2.5 | 36.557 | 18.2 | 146.717 | 11.7 | (-21) | 27 | 3 | Myrtleford |
| 26 Jan | 02:33:34.4 | 0.7 | 36.406 | 8.3 | 146.547 | 3.6 | 6.7 | 2.6 | 3.1 | Everton |
| 28 Jan | 12:02:25.6 | 0.4 | 37.058 | 7.5 | 146.684 | 4.2 | 5.7 | 4.6 | 3 | Mount Speculation |
| 7 Feb | 05:55:00 | | | | | | | | 2-1/2 | Possibly Wilson's Promontory |
| 8 Feb | 01:06:48 | | | | | | | | 2.9 | Possibly vicinity of Upper Howqua River |
| 15 Feb | 11:50:50 | | | | | | | | 2-1/4 | Possibly vicinity Lakes Entrance |
| 6 Mar | 09:00:23.5 | 14.2 | 37.316 | 51.5 | 146.531 | 42.9 | (-22) | 179 | 3 | East of Mount McDonald |
| 9 Mar | 01:00:57 | | 37° 12' | | 147° 33' | | | | 2-1/4 | Onco-Tongio district |
| 16 Mar | 09:38:52 | | 38° 36' | | 146° 18' | | | | 3 | South Gippsland Hills |
| 29 Mar | 00:10:35.7 | 34.8 | 37.898 | 270 | 146.331 | 108 | 18.9 | 211 | 3-1/2 | Walhalla - Mount Baw Baw |
| 2 Apr | 19:09:12 | | 37° 06' | | 144° 21' | | | | 3-1/4 | East of Castlemaine |
| 14 Jun | 19:23:47.8 | 3.7 | 38.657 | 14.9 | 146.425 | 5.7 | 1.6 | 25.7 | 4-3/4 | Welshpool |
| 16 Jun | 18:43:47 | | | | | | | | 3-1/2 | Aftershock |
| 24 Jun | 07:21:49 | | | | | | | | 2.9 | " " |
| 2 Aug | 09:52:24 | | | | | | | | 3-1/2 | Probably Strathbogie Ranges east of Euroa |
| 29 Aug | 05:10: | | 36° 48' | | 147° 30' | | | | 1-3/4 | Near Glen Wills |
| 11 Nov | 23:49:49.5 | 0.8 | 37.888 | 4.8 | 148.090 | 7.2 | 7.9 | 3.8 | 2-1/2 | Off Lakes Entrance |
| 11 Dec | 02:22:37 | | | | | | | | (2-1/2) | Possibly west of Bendigo |
| 25 Dec | 08:48:30 | | 37° 50' | | 146° 12' | | | | 2.9 | Upper reaches of the Tyers River. |

Table 2 (Contd)

| Date | Time GMT | SE (sec) | Lat. | SE (km) | Long | SE (km) | Depth (km) | SE (km) | Mag | Comments |
|-------------|-------------|-------------|---------|------------|----------|------------|---------------|------------|---------|--|
| <u>1965</u> | | | | | | | | | | |
| 14 Sep | 12:53:13 | | 38° 42' | | 144° 18' | | 33(R) | | 5.7 | Near S. E. coast of Australia (U. S. C. G. S.) |
| 14 Sep | 13:15:46 | | | | | | | | | Felt. |
| 14 Sep | 13:55:47 | | | | | | | | 2.9 | Aftershock |
| 14 Sep | 15:47:19 | | | | | | | | 3.3 | " |
| 5 Oct | 15:14: | | | | | | | | 3.1 | " |
| 6 Oct | 00:35:04.2 | 2.2 | 36.508 | 11 | 145.070 | 8.8 | (-3) | 11 | (2) | Possibly vicinity Cape Otway |
| 15 Oct | 14:08:04 | | | | | | | | (2-1/2) | Warrunga Reservoir near Rushworth |
| 24 Oct | 15:48:23.8 | 0.7 | 38.193 | 1.9 | 145.708 | 1.3 | 30.6 | 10.7 | 1-1/2 | West of Mount Useful |
| 2 Nov | 15:23:35 | | | | | | | | 2.1 | Near Modella, N. E. of Western Point Bay |
| 30 Nov | 18:35:20 | | | | | | | | 1-3/4 | Few km south of Korumburra |
| 2 Dec | 08:11:34 | | | | | | | | 2.4 | Off Airey's Inlet |
| | | | | | | | | | 1-3/4 | Probably near "The Nobbies", Phillip Island. |
| <u>1966</u> | | | | | | | | | | |
| 16 Jan | 12:37:26 | | 39° 00' | | 144° 20' | | | | 1-1/2 | Northern Bass Basin |
| 25 Jan | 21:17:43 | | | | | | | | (1.6) | Off East coast of Wilsons Promontory |
| 10 Feb | 01:56:52 | | | | | | | | (1-1/2) | Possibly Strathgogie Ranges |
| 13 Feb | 10:56:22.0 | 2.4 | 38.904 | 12.3 | 145.895 | 6.1 | (62) | 22 | 3.3 | Cape Liptrap |
| 23 Apr | 17:26:33.3 | 1.4 | 37.080 | 10.0 | 146.275 | 6.0 | 0.9 | 18.6 | 2-1/2 | Merrilijig |
| 23 Apr | 17:26:56 | | | | | | | | 2-1/2 | Merrilijig |
| 1 May | 05:09:34.5 | | | | | | | | (3) | Glen Thompson, Western District: Felt. |
| 3 May | 19:07:53.1 | 0.8 | 37.043 | 2.3 | 147.130 | 4.7 | 7.6 | 7.0 | 5-3/4 | Mount Hotham |
| 31 May | 04:18:18 | | | | | | | | 2-1/4 | South West of Wilsons Promontory |
| 5 July | 22:26:39.4 | 5.3 | 39.647 | 5.6 | 144.964 | 31.9 | (62) | 35 | 4.1 | South of Cape Schanck |
| 6 Aug | 15:05:23 | | | | | | | | (2) | Wallan |
| 15 Aug | 22:27:18.2 | 11.8 | 37.957 | 40.6 | 149.121 | 40.7 | 35.6 | 58.7 | 3.2 | South of Cann River |
| 30 Aug | 14:27:24 | | | | | | | | (2-1/2) | Probably vicinity Bendigo |
| 5 Sep | 17:57:51.5 | 4.6 | 36.230 | 17.4 | 144.522 | 22.6 | 17.0 | 21.2 | 3.4 | South West of Echuca |
| 29 Sep | 18:05:52.0 | 7.7 | 38.267 | 34.4 | 146.104 | 15.1 | (-76) | 50 | 3-1/4 | Childers, E. Gippsland |
| 2 Oct | 05:04:54 | | | | | | | | (2) | Undetermined Victorian earthquake |
| 8 Oct | 13:21:14 | | | | | | | | | Dandenong. Felt. |
| 17 Oct | 17:12:50.8 | 6.4 | 37.880 | 62.2 | 146.199 | 37.4 | 18.1 | 48.9 | 3.8 | Headwaters of the Tanjil River |
| 27 Oct | 00:25:46 | | 40° 00' | | 154° 30' | | 0 (R) | | 4-3/4 | South Tasman Sea |
| 27 Oct | 01:06:22 | | 40° 00' | | 149° 45' | | 0 (R) | | 3-1/2 | East of Flinders Island |
| 3 Nov | 06:13:19 | | | | | | | | (1-1/2) | Vicinity of Cape Otway |
| 13 Nov | 20:56:15 | | | | | | | | 3-1/2 | Between Boort and Pyramid Hill |
| 15 Nov | 21:28:00 | | 38° 30' | | 144° 42' | | | | (2) | West of Cape Schanck |
| 30 Nov | 15:30:25 | | | | | | | | (2-1/2) | Possibly vicinity Pyramid Hill |
| 15 Dec | 19:06:29.1 | | 40° 24' | | 155° 24' | | 33 (R) | | 5-1/2 | South East of Australia (U. S. C. G. S.) |

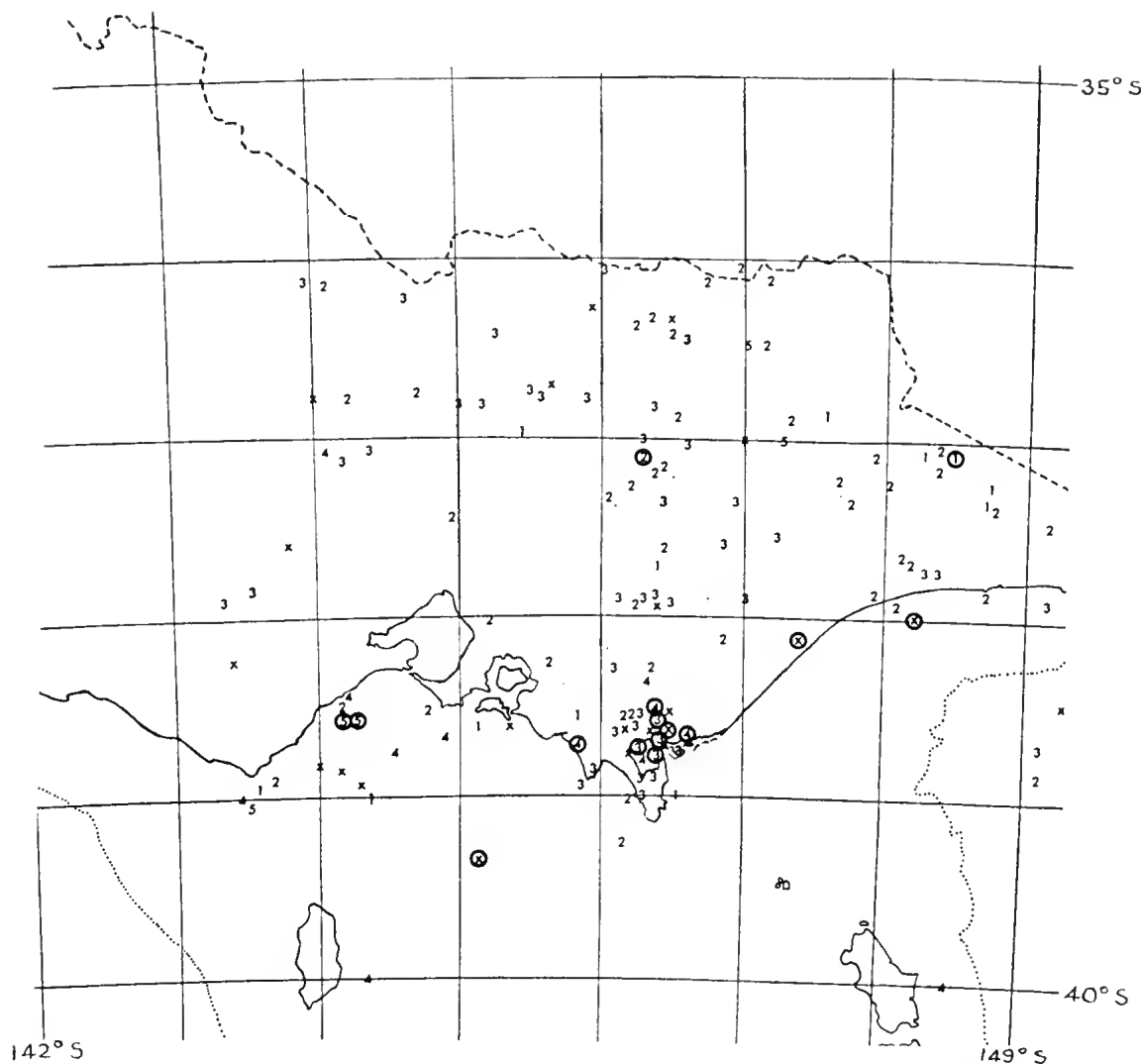


FIG. 2—Seismicity of Victoria 1959-1966 inclusive. The magnitude numbers are plotted at the computed epicentre. A ring indicates aftershocks; an x indicates an inaccurate location.

(4) Earthquakes located near Melbourne, and in the western part of Gippsland, are rare compared with the historical record. One difficulty in studies of small earthquakes is to distinguish these from large quarry blasts, especially round centres of population and industry, and it is possible that a few earthquakes have been wrongly rejected because they chanced to occur during working hours when blasts are likely. But there seems to have been a real diminution in seismic activity in West Gippsland.

(5) High activity occurs along the coast east of Cape Otway. The largest earthquake of the period studied, magnitude 5.7 on 14 September 1965, occurred in this area, and it was preceded by a

magnitude 5.0 shock 20 minutes earlier. There were several aftershocks. The accuracy of location in this area is not good, so that the question whether the activity is associated with either or both of the faults mapped along and off this coast (Weeks and Hopkins 1967) cannot be answered by this study.

(6) An interesting feature of the seismicity is an association between earthquakes in the central Tasman Sea, near Lat. 40°S., Long. 155°E. (off the edge of Fig. 2) and others at the same latitude just east of Flinders Island. On two occasions, earthquakes of the eastern group have been followed by shocks at the western end. There have also been unassociated shocks.

| | <i>G.M.T.</i> | <i>Lat.</i> | <i>Long.</i> | | |
|--------------|---------------|-------------|--------------|--------|-------------------|
| 1961 Jan. 22 | 14:43:55 | 39°30'S. | 155°30'E. | M = 4 | S. Tasman Sea |
| " " 22 | 18:39:45 | 40°S. | 155°30'E. | M = 4 | S. Tasman Sea |
| " Feb. 3 | 14:37:45 | 40°S. | 148°30'E. | M = 4 | E. of Flinders I. |
| 1966 Oct. 27 | 00:25:46 | 40°S. | 154°30'E. | M = 4½ | S. Tasman Sea |
| " " 27 | 01:06:22 | 40°S. | 149°45'E. | M = 3½ | E. of Flinders I. |

UNASSOCIATED SHOCKS

| | | | | | |
|---------------|------------|----------|-----------|--------|--------------------------------------|
| 1961 Sept. 12 | 07:13:09 | 40°7'S. | 156°6'E. | M = 4½ | S. Tasman Sea |
| 1966 Mar. 18 | 18:09:31.1 | 40°12'S. | 149°36'E. | M = 5 | Continental slope, E. of Flinders I. |
| " Dec. 15 | 19:08:29.1 | 40°24'S. | 155°24'E. | M = 5½ | S. Tasman Sea |

A search through the results for January 1967 has not revealed any shocks near Flinders Island that could be associated with the last of these.

There does not seem to be any east-west feature in the topography of the sea floor near Lat. 40°S. that could correspond to the seismic pattern, and the central Tasman epicentres are beyond a major ridge trending NNE.-SSW. These shocks may be mislocated by a considerable distance. Soundings, and marine refraction profiles to establish mantle P velocities, preparatory to a careful re-determination of shocks in the Tasman Sea, would be worthwhile projects.

(7) Near Moondarra (Lat. 38°02'S., Long. 146°22'E.) in Gippsland, there is an active seismic area. The existence of this feature is confirmed by the number of historical reports of earthquakes felt in the area. To the writer's knowledge, its presence has not previously been noted, but as it is beside the developing industrial and population concentration of the Latrobe Valley, further study is obviously desirable.

From the present study, it appears that the epicentres are all in the hills to the north of the fault bounding the Gippsland basin, and that the active area is elongated east-west, in contrast to the generally meridional trend of the Palaeozoic in these hills. It may be significant that the bounding fault hinges in this vicinity, because the corresponding fault to the south of the Gippsland basin also hinges near an active seismic zone, in the South Gippsland Hills (Weeks and Hopkins 1967, Fig. 6).

(8) Seismicity studies based on only the larger events may be misleading. For example, the USCGS events in Table 2 would indicate hardly any seismicity on the mainland, as they are mostly in Bass Strait. But the risk of damaging shaking at a site arises largely from smaller events which may occur at short epicentral distances, and Fig. 2 shows many of these in Victoria. Table 2 is complete for all events capable of causing damage, at least for Eastern Victoria.

RECURRENCE RELATIONSHIPS

The probability distribution of earthquakes with magnitude provides a convenient summary of seismic activity. The parameters can be used for comparisons between regions, and for the calculation of extreme value statistics useful in designing engineering works.

From Table 2, the number of shocks in intervals of one half of a magnitude unit were counted, and a cumulative graph drawn (Fig. 3). The ordinate has a logarithmic scale. Fitting a formula of the type

$$\log_{10} N = A - bM$$

where N is the number of shocks of magnitude M or less, to the linear portion of the graph by eye gives

$$A = 3.71 \quad b = 0.6$$

Below magnitude 3½ the number of shocks recorded falls increasingly below the straight line. This is inevitable because smaller earthquakes are lost in the background of noise. For a more closely spaced network the magnitude below which earthquakes are lost is smaller. For example, the Dalton curve on the same figure is linear down to about 2½ and the Snowy curve probably down to about 2. For high magnitudes, the smallness of the sample causes some instability.

It is unusual for the b value to be so low; typical values cluster round 0.8 to 1.0 (Isaacs and Oliver 1964; Ryall, Slemmons and Gedney 1966), while experiments on the fracture of heterogeneous materials give b values in the range 0.5 to 1.5 (Mogi 1962). The low Victorian value implies that there are more earthquakes of larger magnitude than might be expected from a world-wide coverage. This contrasts with the Dalton-Gunning region in New South Wales, where an analysis of the data by Cleary (1967) gives

$$\log_{10} N = 5.1 - 1.45 M$$

That is to say, there are many small shocks and few large ones in the Dalton-Gunning region. The

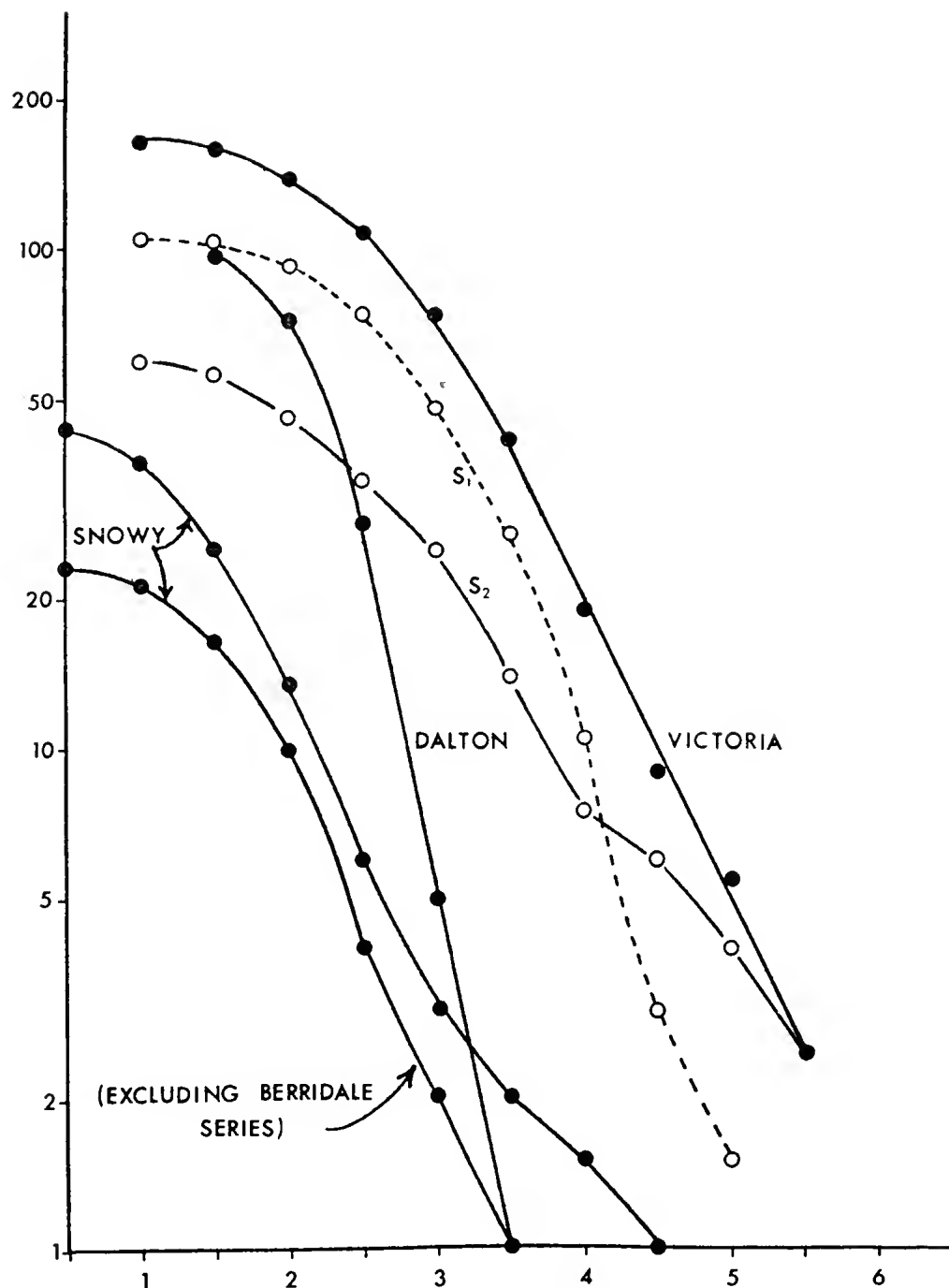


FIG. 3—Earthquake recurrence diagrams for south-eastern Australian seismic areas (see text).

data from the Snowy Mountains region extracted from Cleary, Doyle and Moye (1964) are also plotted in Fig. 3, both with and without the Berri-dale sequence. It shows a complicated behaviour,

somewhat perturbed by the smallness of the sample, with the value of b about 0.6.

As discussed below, the Victorian data may be divided into periods before and after 1 November

1964. These are the S_1 and S_2 lines in Fig. 3. The straight line segments are

For S_1 :

$$\log_{10} N = 4.14 - 0.790 M; \Delta M = 0.5, N = 104$$

For S_2 :

$$\log_{10} N = 10.31 - 0.397 M; \Delta M = 0.5, N = 60$$

but the samples are rather small. The S_1 period has a normal 'b' value. The very low 'b' for the S_2 period is because there are many earthquakes of magnitude 4 and above.

TIME SEQUENCE ANALYSIS

If the earthquakes are perfectly independent, rare (that is, isolated), random events, all of which are equally probable, then the number of events per unit time interval should be distributed with a Poisson law (Lomnitz 1966). The earthquakes in Table 2 were counted in one-month

intervals (Fig. 4, third histogram) and the historical data in Table 1 were counted in one-year intervals (Fig. 4, first histogram). Chi-square tests on the index of dispersion (the ratio of variance to mean) showed that there was negligible probability of either histogram being from a Poisson distribution, the major contribution to the statistic coming from the great number of zero-event intervals. Deviations from the Poisson law can be due to:

(1) Failure to detect all of the small magnitude events. That this is important can be demonstrated by removing all of the shocks $M < 3\frac{1}{4}$ (Fig. 4, second histogram), which indeed increases the number of empty intervals. However, it does not seem possible to reconstruct the distribution of all shocks, including unobserved small ones, without making some further assumptions.

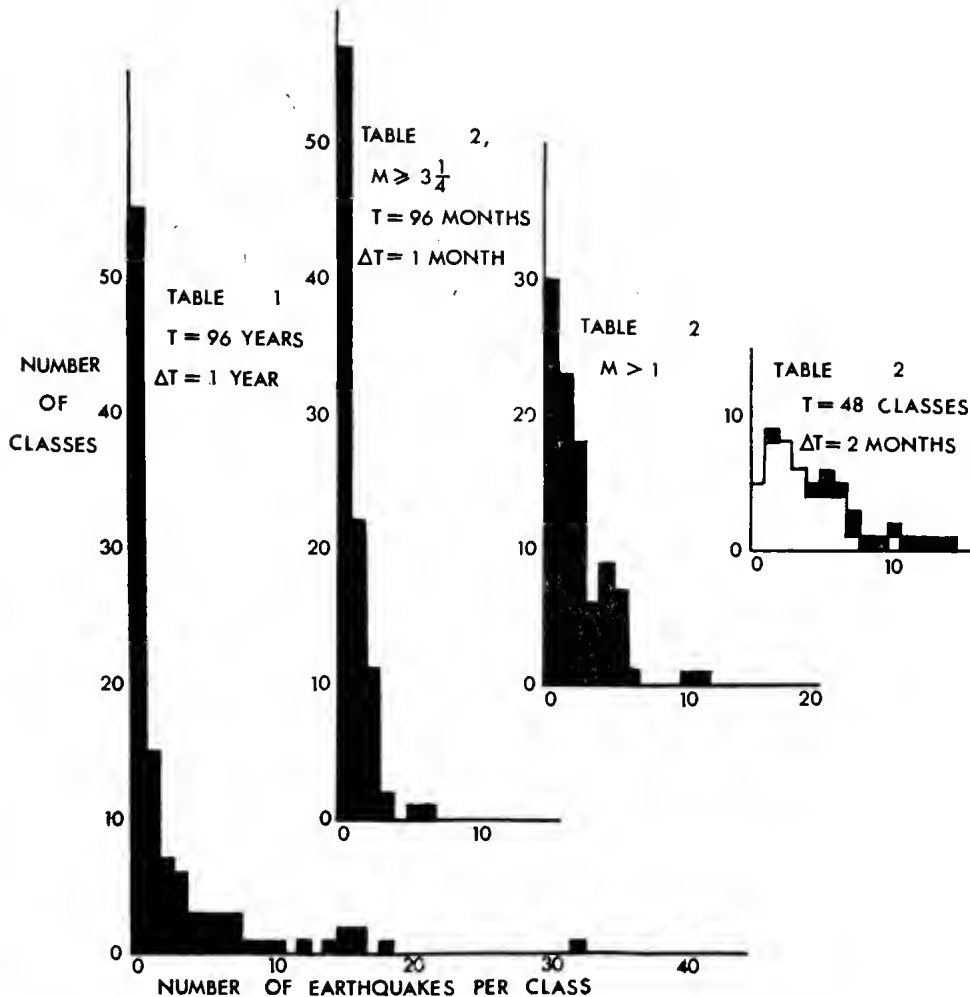


FIG. 4—Histograms of the frequency with which the time interval ΔT had the stated number of earthquakes, in Victoria.

(2) Space inhomogeneity, as demonstrated by Fig. 1 and 2.

(3) Non-stationarity of the time sequence, which can be shown to be present at the 5 per cent significance level by a Kolmogorov-Smirnov test on the cumulative count of all earthquakes as a function of time. There was a sudden significant change in trend in August 1964, with shocks in the South Gippsland Hills and Bass Strait, and about three months before the change in strain release discussed in the next section. Neither portion of the data has a Poisson distribution.

(4) Clustering of events is certainly a major reason for deviation from the Poisson distribution. An inspection of Table 2 shows several aftershock sequences, and these events are by definition not independent. But a reasonable assumption is that the influence of one shock on the probability of occurrence of a succeeding one is a decreasing function of time, so that taking counts over successively longer intervals of time should lead to closer approximations to the Poisson model. The fourth histogram of Fig. 4 illustrates this for two-month intervals. (With a small quantity of data, the arbitrary choice of starting time introduces fluctuations. Both odd and even starting months are shown, to illustrate this.) Further analysis shows that significant correlation between events persist to about two months at least.

There are not, however, any significant periodic effects in the data. This can be shown by spectral methods, but it is perhaps sufficient to remark that the index of dispersion is significantly greater than one, indicating clustering, whereas periodic data would be underdispersed. Moreover, any recurring effect would necessitate a period exceeding four months (because this is the longest interval observed between events), but correlation between numbers of events in intervals as long as this is insignificant.

STRAIN RELEASE

To gain a deeper understanding of the tectonic process it is necessary to combine the magnitude and number analyses, and this can be done by accumulating a quantity called 'strain' as a function of time:

$$\text{strain} = J^{\frac{1}{2}} = \text{antilog } (4.5 + 0.9 M)$$

This formula is based on the energetics of a simple earthquake model, where the rocks in the vicinity of a fault accumulate elastic strain energy, proportional to the square of the strain, until it is released when the fault slips to produce an earthquake. A proportion of the energy released goes into vibrations which are recorded, and sealed in the logarithmic form as magnitude. The constants are chosen to allow direct comparison with

other work. Although the model is simple linear, and elastic, we are interested mainly in changes in the time trend of strain, and need make no such assumptions about the underlying tectonic processes. The strain release computed for all the earthquakes of Table 2 is plotted in Fig. 5.

Clearly, two quite different types of tectonic regime have been acting. The first appears to have commenced about 1959 although detailed results did not begin to accumulate until this time, when new stations began to operate. Strain release is proportional to the logarithm of time:

$$S_1 = (0.878 \log T - 2.15) 10^{10}$$

where S is the strain release in $(\text{erg})^{\frac{1}{2}}$ and T is the time in days from 1 January 1959. Commencing in October or November 1964, strain release has been linear with time

$$S_2 = (0.002135 T - 3.86) 10^{10}$$

and this new regime continues to the end of 1966.

This may be interpreted as a 'locking' sequence (Benioff 1955). During the S_1 regime, the parts of the area were locked tightly together so as to act as a single unit to external strain. The earthquakes within the area were in the nature of readjustments of strain accumulated from prior to locking, and the rate of strain release at any one time was proportional to the strain remaining at that time. In the second half of 1964, the locking began to weaken, and it is tempting to identify the magnitude 4.4 earthquake in a somewhat unusual position between King Island and north-west Tasmania on the 14 November 1964 as the final 'breaking' of the lock. Since then, strain has been released at a rate governed by the rate of accumulation, which is linear with time. This rate is only one to ten per cent of the rate in active regions, however:

| | |
|---------------|------------------------------------|
| Victoria | $B = 0.2 \times 10^8$ |
| Deep Kermadec | $B = 161.0 \times 10^8$ |
| Deep South | |
| American | $B = 73.0 \times 10^8$ after 1932 |
| Deep South | |
| American | $B = 15.9 \times 10^8$ before 1922 |
| Shallow South | |
| American | $B = 153.0 \times 10^8$ after 1922 |

(data from Benioff (1949, 1955))

The form of the S_1 curve is also often observed in aftershock sequences; extrapolating to earlier time indicates an initiation time no earlier than the end of 1958. There seems to have been no large enough shock in Victoria during this time, but the magnitude 5 earthquake of 18 May 1959, near Berridale in the Snowy Mountains (Cleary, Doyle and Moye 1964), may have locked the Victorian region, and initiated the S_1 regime. One

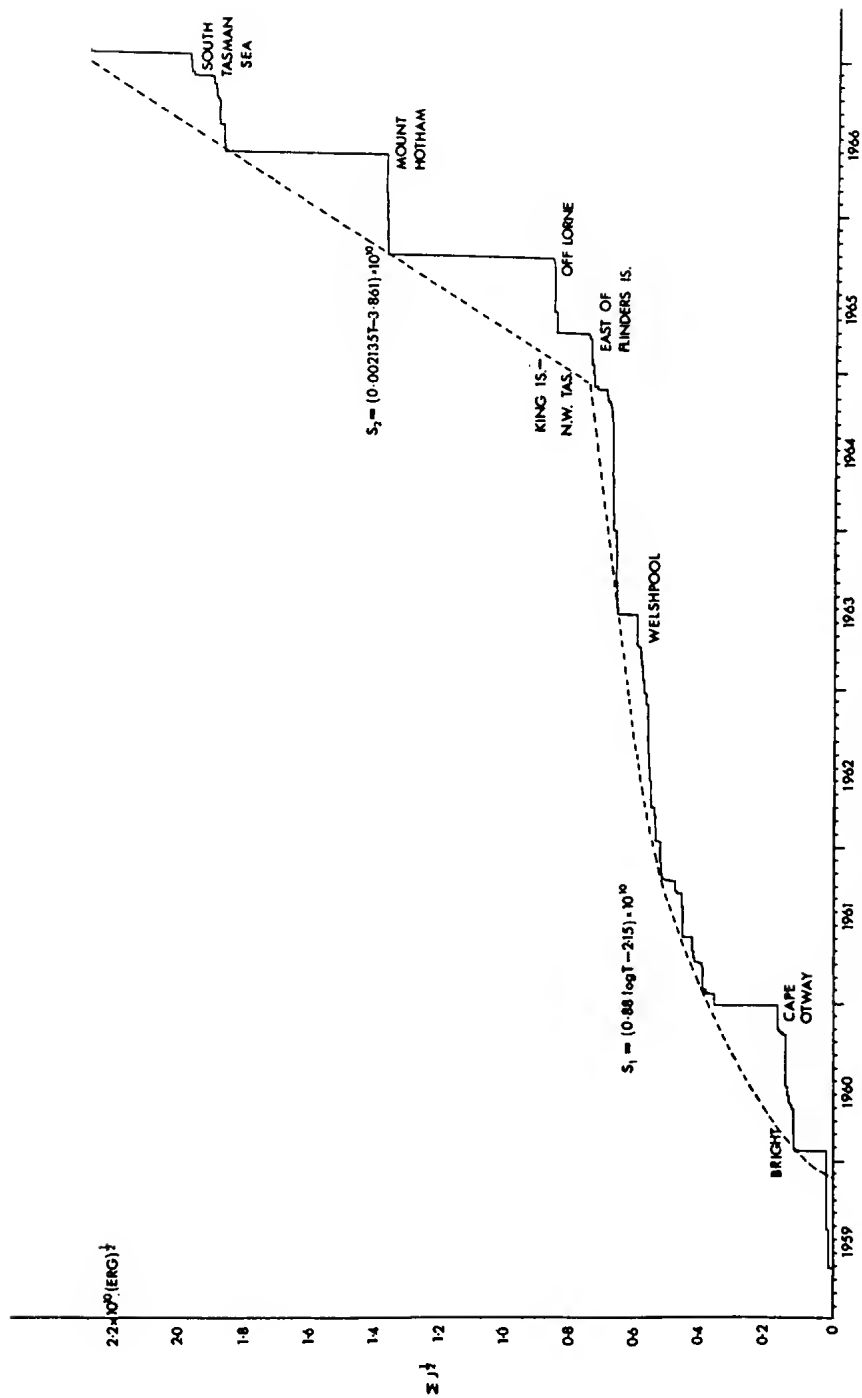


FIG. 5—Strain release diagram for Victorian earthquakes.

might speculate that while the Victorian area was not releasing externally accumulating strain, but responding as a unit, the strain built up in adjacent regions until a different locality failed, and this was the Robertson area south of Sydney, where a magnitude $5\frac{1}{2}$ shock occurred on 21 May 1961.

To bring the analysis as far as possible up to date, the events from the end of 1966 to mid-1970 have been examined in the same fashion. Both numbers of events and their strain release decreased from 1967 to mid-1969. On 20 June of that year, a magnitude 6.0 earthquake occurred at Boolarra in South Gippsland, followed by many aftershocks. The strain release for this new data is definitely less than during the S_2 regime, and it does not seem to form a continuation of earlier activity according to any recognizable creep law. It seems clear that a new locking sequence is beginning in Victoria but a detailed analysis is not yet possible.

NODAL ANALYSIS

When an earthquake is recorded at a number of stations, the direction of ground motion of the initial P impulse is found to be 'up' at some, and 'down' at other sites. This distribution is a mappable quantity, and if the seismic rays are traced back to correct for the known structure of the earth, the corrected pattern is very simple. The lines dividing 'up' from 'down' are usually found to be readily interpreted as the traces of two 'nodal' planes orthogonal at the earthquake focus. By hypothesis, one plane is identified as the 'fault' plane in which motion has occurred, and the other as the 'auxiliary' plane, but from P observations alone it is not possible to decide which is which. For details of the theory and method see Cleary, Doyle and Moya (1964), Cleary (1963) and Underwood (1967). By further hypothesis, principal stress axes may be deduced from either plane if an angle of slip is assumed. Usually the angle of slip is assumed to be 45° ; i.e., it is assumed that the faulting occurred on the plane of maximum shear stress, because the two sets of principal stress axes coincide in this case. Alternatively, some assumption is made about the stress, so that the slip angle can be calculated.

Only a few of the largest Victorian earthquakes have been sufficiently well recorded to enable this method to be employed. These are the Bright (1960), Cape Otway (1960), and the shock off Lorne (1965). Summarizing these, along with all the other earthquakes in south-east Australia for which solutions have been obtained (Cleary 1963, Underwood 1967) by plotting poles and axes on a lower hemisphere Wulff stereogram, and assum-

ing 45° angle of slip results in the consistent pattern shown in Fig. 6. Open symbols represent reverse fault movements, the squares being the poles of the preferred fault planes, and the circles poles of the auxiliary planes. The principal stress axes are represented by P for compression and T for tension axes, with a plus sign for the intermediate stress axis.

It is apparent that there is a tendency for tension axes to be near vertical, and the compressive axes cluster between west and northwest, but with moderate plunges. Equilibrium of the whole area demands that the average compressive stress be horizontal. Assuming this to be the case, the angles of slip come out to be rather uniformly distributed from 0 to 90° , and a chi-squared test shows that there is no preferred average angle of slip. The average azimuth of the P axes rotated to the horizontal is 298° . If the pattern indicates the response of south-east Australia to tectonic forces, then these forces are compressions from southeast and northwest.

DISCUSSION

Earthquakes in Victoria occur mainly in the eastern half of the State, and there are three active areas: in the South Gippsland Hills, near Moon-darra, and off the Otway coast. The shocks are not independent events, and appear to be in response to horizontal compression on a southeast-northwest line. In the period studied instrumentally, two types of behaviour occurred. The first commenced about the end of 1958, the strain release being logarithmic with time, and the recurrence ratio b being close to a normal value of 0.8. Then from mid-November 1964, strain release became linear with time, and there was an anomalously large number of earthquakes of magnitude 4 or greater.

The picture which has emerged from the seismic studies foreshadowed by Jaeger and Browne (1958) is one of variability of the seismicity pattern, a variability which is the more apparent because of the minor scale of the activity. At some times the whole of south-east Australia is quiet, and at others particular areas suffer series of earthquakes. Even in the areas of known seismic activity, there are fluctuations in the detailed pattern (Cleary 1967). Victoria certainly has an earthquake history of this variable character.

It may be instructive to draw these facts into the framework of a causal theory, which although speculative, will suggest fruitful further investigations. Forces directed to the northwest from the Tasman Sea are compressing the whole of south-east Australia. The crust is reacting mainly by movements on, and perhaps extensions of, suitably

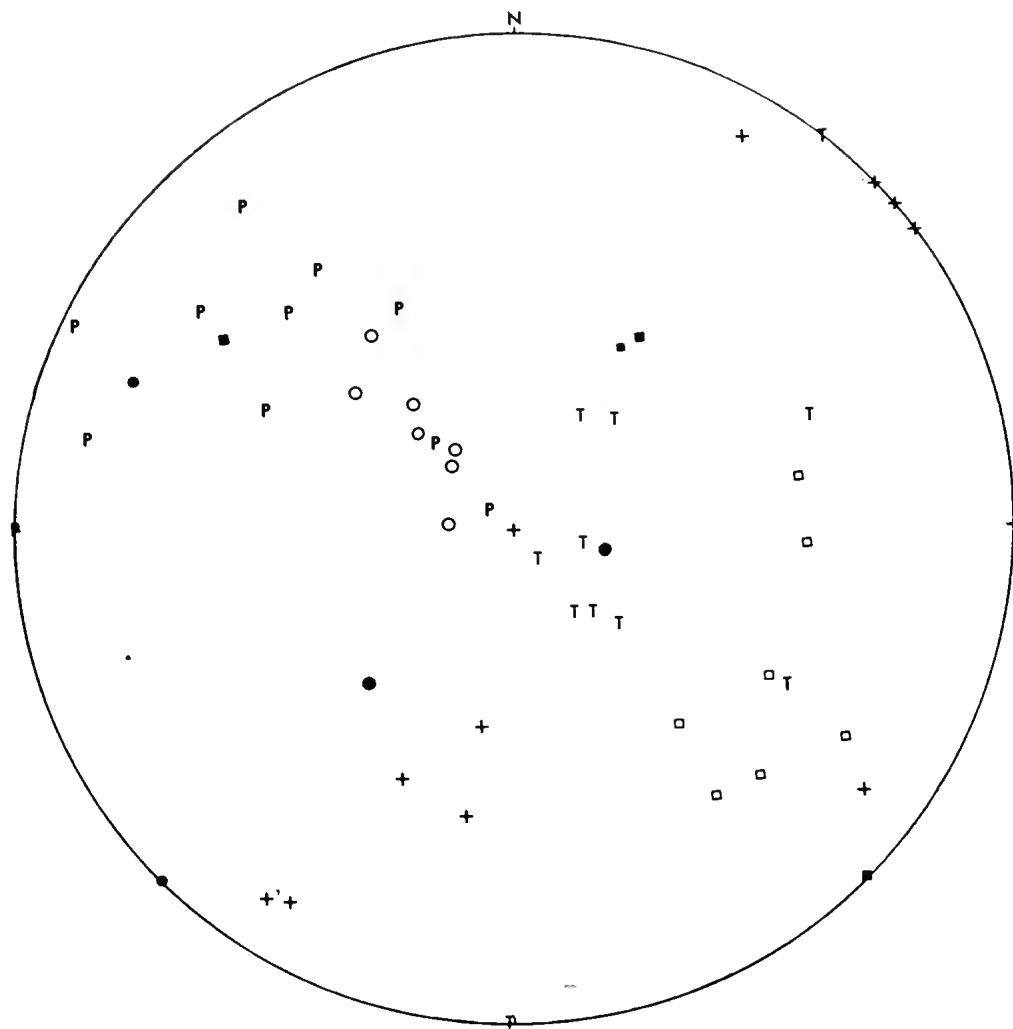


FIG. 6—Summary of south-eastern Australian focal mechanism solutions. Stereographic projection on the lower hemisphere.

oriented old faults. In Victoria, there are three main fault zones of this description. Movements between blocks tend to interfere with each other, and an earthquake may 'lock' a whole region in such a way that the main force field is bridged away through interlocking blocks to other parts of south-east Australia, leaving a core of relatively unstressed country which is free to relieve the previously imposed strain by small internal readjustments, which it does at a rate proportional to the remaining strain. The surrounding areas are thrown into a state of increased stress, and shocks in unusual locations may be experienced, until the 'lock' is broken. The force field then acts on the relaxed area, and most of the strain release is concentrated here for a time. The next stage could be that the movements begin again to inter-

fere one with another, the area will 'work harden' so that a larger number of smaller earthquakes will occur in Victoria and the seismic activity will spread more uniformly over south-east Australia. In a few more years, enough seismicity studies will have been completed in south-east Australia, to make a thorough test of these speculations possible.

ACKNOWLEDGMENTS

The work reported here was done while I was in receipt of a post-graduate scholarship, and forms part of a thesis submitted to the Australian National University. The historical investigations were commenced when I was employed at the Bureau of Mineral Resources, to the Director of which I am indebted for permission to publish the

information of Table 1. The work was initiated by Mr. H. A. Doyle, and I am also indebted to Professor J. C. Jaeger and Dr. J. R. Cleary for support and encouragement.

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APPENDIX

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EUCALYPTUS CALOPHYLLA VAR. *MAIDENIANA* HOCHR.: A MALE TREE

By STELLA G. M. CARR* and D. J. CARR*

ABSTRACT: As previously predicted, *E. calophylla* var. *maideniana* is shown to consist of material collected from an apparently male tree of that species.

Some species of series *Corymbosae* (Benth.) Maiden, (bloodwoods), including *E. calophylla* (R. Br.) ex Lindl., *E. ficifolia* F. Muell., and *E. haematoxylon* Maiden have recently been shown to produce 'male flowers' (Carr, Carr and Ross 1971) (see footnote). In its extreme form, the male flower of these eucalypts is sub-spherical or top-shaped due to almost complete failure of the ovary to develop. Examination of material from trees which habitually set few fruits showed that even flowers of an apparently normal shape may be functionally male, due to late failure of ovule or embryo sac development. Some trees of *E. calophylla* appear to bear only male flowers and set either no fruits or a few which are aberrant in shape or contain no seeds. From its description we suggested (Carr, Carr and Ross, loc. cit.) that *E. calophylla* var. *maideniana* Hochr. might have been based on material collected from such a male tree. At that time the type material was not available to us for inspection but it has since been sent on loan by courtesy of the Curator of the Boissier Herbarium in Geneva. In the meantime, Pryor and Johnson (1971) have synonymized the variety with *E. haematoxylon* without, it would appear, an examination of the type material.

One sheet of the type is illustrated in Fig. 1. The shape of the buds indicates that all are male (compare Fig. 2 with Figs. 1-7 of Carr, Carr and Ross 1971). Longitudinal (Fig. 7) and transverse (Fig. 3) sections of a typical flower bud confirm that the ovary is completely abortive. Ovulodes are incompletely developed and the ovules are typically collapsed (Fig. 9). The tree from which the type material was collected bore no fruits (Hochreutiner 1924-26). Although taxonomically the variety cannot be maintained, Hochreutiner's specimen is of interest as the first record of a male tree of *E. calophylla*. Unlike the specimens

described in Carr, Carr and Ross (loc. cit.) all of the flowers of the type specimen are of the extreme male type, with little or no development of the ovary. The flowers of the type specimen differ in a number of respects from the extreme male flowers described by Carr, Carr and Ross. They have relatively long pedicels, a considerable development of the duct system of the ovary wall (Figs. 3, 4 and 8), a normal development of the large central cavity (traversed by frayed strands of parenchyma), of the style (Fig. 5), and a well-developed compitum (Fig. 8). These are all features well shown in bisexual flowers and in superficially bisexual flowers rendered male by collapse of the ovules at an early or late stage in embryo sac development (cf. Fig. 10 of Carr, Carr and Ross 1971). However, it is clear that in the Hochreutiner specimen completeness of anatomical development is not related to the shape of the flower. The nectary and stamens of these male flowers are always normally developed and the pollen appears normal (Fig. 6).

E. calophylla, *E. ficifolia* and *E. haematoxylon* are all confined to the south-west province of Western Australia. They appear to be closely related. Herbarium specimens or trees in cultivation are not readily identifiable to the species. *E. calophylla* and *E. ficifolia* are vicarious. It has recently been shown that the latter is more susceptible to a soil-borne disease ('stem canker') the causal organism of which occurs in soils which carry stands of *E. calophylla* but is absent from soils on which *E. ficifolia* is native (Smith 1970). There seems no adequate reason to separate *E. ficifolia* from the other two into a special 'sub-species *Ficifolinae*', as proposed by Pryor and Johnson (1971). In this instance, specific differences in the presence or absence of a wing on the seeds are irrelevant, as was perceived by Bentham

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(1867) and confirmed by Gauba and Pryor (1961). However, it is useful to note that *E. haematoxylon* differs from the other two species in that the style is inserted in a pit, a character hitherto unrecorded. In *E. calophylla* and *E. ficifolia* the base of the style joins smoothly and squarely to the free surface of the ovary—there is no depression around the base of the style. This is also true of the style of the flower of *E. calophylla* var. *maideniana* (Fig. 8).

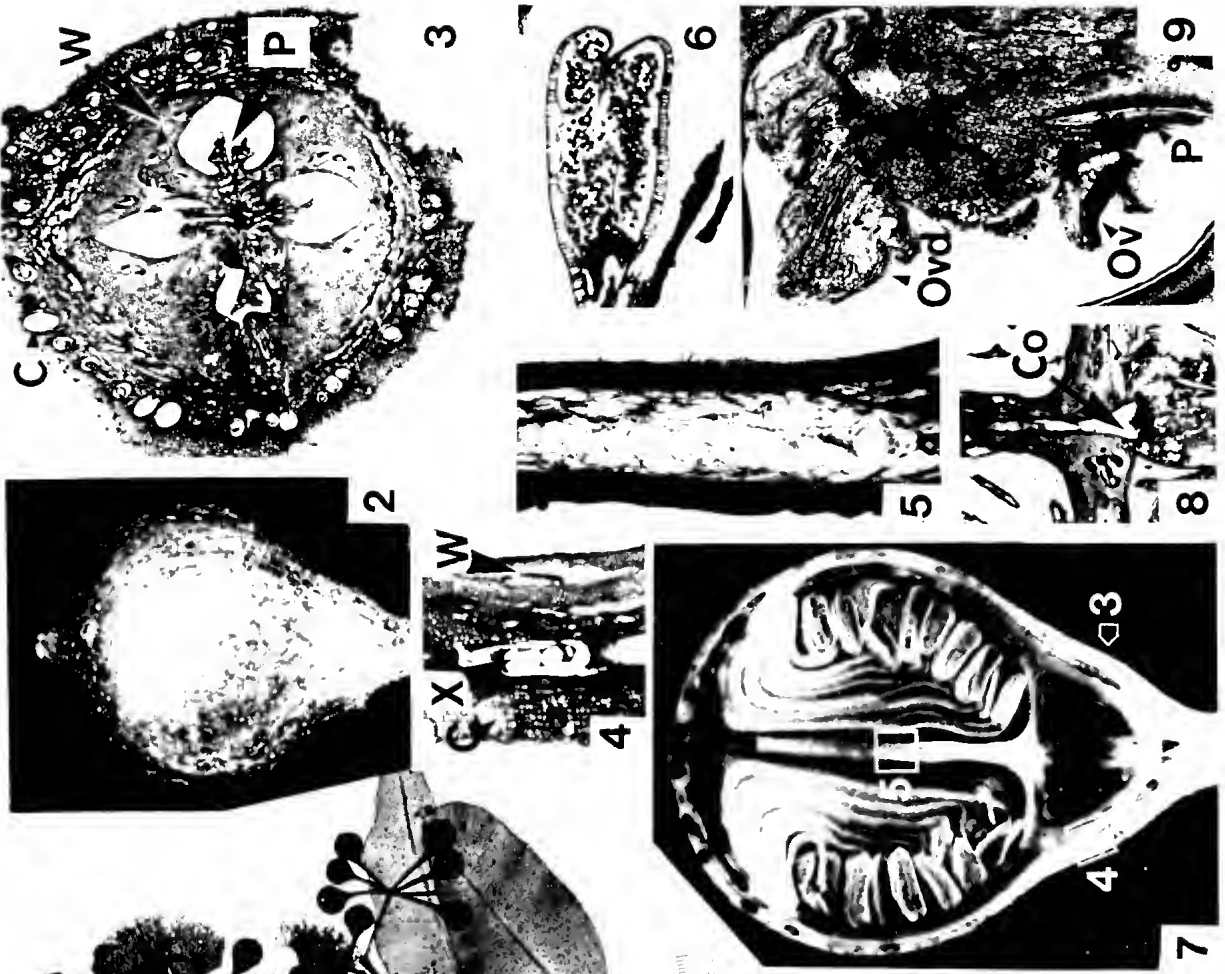
NOTE ADDED IN PROOF: Male flowers were reported by G. Benthams (1869: Notes on Myrtaceae. *J. Linn Soc. (Bot.)* 10: 101-166) as occurring in 'a number of genera in Leptospermoideae'. S. T. Blake (1968) has also remarked of *Melaleuca leucadendron* that 'some plants produce only male flowers' (A revision of *Melaleuca leucadendron* and its allies (Myrtaceae). *Contrib. from the Queensland Herb.* 1: 1-114).

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DESCRIPTION OF PLATE 4

- FIG. 1—Type specimen ($\times 0.5$).
- FIG. 2—Typical flower bud ($\times 4.5$).
- FIG. 3—Transverse section of ovary ($\times 20$). C = cortical oil glands, W = ducts of ovary wall, P = placenta with abortive ovules.
- FIG. 4—Longitudinal section of outer portion of the ovary. X = ducts accompanying X bundles (see Carr, Carr and Milkovits 1970). Other lettering as in Fig. 3 ($\times 50$).
- FIG. 5—Longitudinal section of mid-region of style, showing the central cavity traversed by strands of parenchyma ($\times 50$).
- FIG. 6—Longitudinal section of an anther, showing the content of apparently normal pollen ($\times 30$).
- FIG. 7—Median longitudinal section of a typical flower ($\times 7$). The plane of section of Fig. 3 is indicated by an arrow. The portions of the bud sectioned in Figs. 4 and 5 are also indicated.
- FIG. 8—Median longitudinal section of the base of the style, showing its smooth, square confluence with the free wall of the ovary. Note the well-developed compitum (=Co) ($\times 20$).
- FIG. 9—Longitudinal section of ovary showing a placenta (=P) bearing ovulodes (=Ovd) and a collapsed ovule (=Ov) ($\times 50$).



B. P. G. Hochreutiner

2950 *Eucalyptus calypso* Lyall, R. B.
var. *macdonnellii* Hook. f. & Th. ex B.
3m
Blacks
W. Australia, Darling Range, 6/1/Ed
Perth. Forest of Eucalyptus & Banksia

EVOLUTION OF THE PERAMELID TARSUS

By LARRY G. MARSHALL*

ABSTRACT: In peramelids, the ectocuneiform bone is incorporated into partial support of the fourth metatarsal, a character unique to that family of Australian marsupials. The incorporation of this bone into support of metatarsal four allows the greater part of the body weight of the animal to pass from the astragalus to the distal tarsals bypassing to a great extent the calcaneum. Such changes in the tarsal arrangement have been influenced by the antecedent development of syndactyly. A similar transfer of body weight, bypassing the calcaneum, occurs in ungulates.

Selected aspects of the hindlimb osteology of peramelids are described and the functional significance of these features is discussed.

INTRODUCTION

Animals of distant phylogenetic relationships often exhibit similar structural adaptations when subject to similar environmental conditions, i.e. convergence. The tarsal bones of various mammals afford a good example of convergence because of their role in locomotion. They are situated between the pes and lower leg, and transfer the body weight to the foot. Any modifications of the tarsals which channels the vector of weight transfer into a single axial component will inevitably be advantageous to the animal. Animals which progress by similar modes of locomotion should thus exhibit similar adaptations in the tarsal region.

Of the Australian quadruped marsupials, the Peramelidae show modifications of the digits and a tarsal arrangement which converges functionally with those of ungulates. This tarsal arrangement, however, is quite different from that seen in any other groups of similarly adapted animal. In peramelids the ectocuneiform assumes partial support of the fourth metatarsal, while in other animals its function is solely the support of the third metatarsal. This unique arrangement has resulted from the antecedent development of syndactyly.

Bensley (1903) in discussing the foot structures of macropods and peramelids states as a footnote (p. 177) 'The arrangement of the tarsals and metatarsals furnishes a point of distinction. In the Peramelidae the enlarged fourth metatarsal is supported in part by the ectocuneiform and in part by the cuboid, while in the Macropodidae it is practically supported by the cuboid bone'. No

further mention of this 'unique tarsal arrangement' is noted in the literature, nor has the function of such an arrangement been proposed. In this paper selected aspects of the hindlimb osteology of peramelids are described and the functional significance of these features is discussed.

DESCRIPTION

In order to discuss tarsal modifications and interpret their functional advantage, it is necessary to establish the primitive arrangement of these bones. Figure 1A depicts the tarsal arrangement as it probably occurred in the ancestors of both Eutherian and Metatherian mammals. Among Australian marsupials, *Dasyurus* shows a remarkably similar hind foot structure, identical in fact in the tarsal arrangement, to the generalized Eutherian pes illustrated in Hildebrand (1960, p. 153). For the purpose of this paper I have designated the pes of *Dasyurus* as exhibiting the non-specialized marsupial tarsal arrangement, and as I will show later the specializations in foot structure shown by peramelids, phalangers and macropods may be readily derived from a dasyurid ancestral type.

In the ancestral tarsal arrangement, the astragalus rests essentially on top of the body of the calcaneum with part of the body weight transferred directly to the calcaneum. The articular surfaces of the calcaneum and astragalus with the distal tarsals are nearly equal in area. This indicates a uniform distribution of body weight from the proximal (astragalus and calcaneum) to the distal (navicular, cuboid, and cuneiforms)

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tarsals. All digits are of approximately equal length.

Cursorial quadrupeds inhabiting open flat areas show reduction of lateral digits leading to functional monodactylism, as exemplified by perissodactyls, or didactylism, as occurs in artiodactyls. Associated with digital reduction is an increase in length of the lower leg and foot both absolutely and in relation to the length of the femur (Lull 1904). The contact of the foot with the ground has become restricted to the ends of the digits, which is in contrast to the palmar contact of ancestral stages.

Accompanying these changes, the distal tarsals show greater consolidation either by fusion or elimination of elements. Deepening of the tibial trochlea and associated lengthening of the medial and lateral malleolus along the sides of the astragalus, restricts the foot to anterior-posterior movement.

The astragalus and calcaneum also assume a new relationship. With greater modification in the direction of quadrupedal mono- or didactylism, and greater elevation of the heel from the ground, the body weight is transferred directly from the astragalus to the distal tarsals rather than through the astragalus and calcaneum. The attainment of a quadrilateral shape of the astragalus is associated with these changes.

In perissodactyls (Fig. 1B) this transfer results from an increase in size of the tarsals which function in support of digit three in the ancestral condition. Tarsals not associated with digit three have either fused (entocuneiform and mesocuneiform) or reduced in size (cuboid and calcaneum). In horses the cuboid, although proportionately reduced, is incorporated into support of metatarsal three. Since the astragalus supported digit three via the navicular and ectocuneiform in the ancestral condition, it is these bones which assume support and consequent transfer of body weight.

In artiodactyls (Fig. 1C) the cuboid, ectocuneiform and navicular assume a larger size in response to enlargement of digits three and four while, as a result of digital reduction and functional loss, the entocuneiform is greatly reduced. The mesocuneiform has fused with the ectocuneiform and in the more cursorially specialized artiodactyls (i.e. Pudu, Fig. 1C) the cuboid and navicular are also fused. The cuboid assumes a greater support of the astragalus with consequent crowding of the calcaneum. Any support of the body weight previously attributed to the calcaneum is lost. The astragalus assumes the full role of transfer of body weight to the distal tarsals. Thus, the distal bones of the ungulate tarsus show changes in mechanical relationship associated with

the reduction of digits. The latter is clearly the primary adaptation although tarsal modifications resulting in more direct weight transfer are seen to be closely associated with digital reduction. It is along these lines, digital reduction and a more direct line of weight transfer, that peramelids show a similar adaptation to ungulates.

In peramelids, however, matters have been complicated by the antecedent development of syndactyly in the hind foot. Digits two and three become enclosed in a skin sheath, functioning as a grooming organ; digits one and five are reduced. Digit four is enlarged and assumes total support of the body weight. In the ancestral tarsal arrangement the proximal tarsal contacting digit four (as well as digit five) is the cuboid and this in turn contacts proximally with the calcaneum; thus if the body weight is to be transferred directly to digit four by-passing the calcaneum and paralleling the structural adaptations seen in ungulates, a marked rearrangement of tarsals will have to occur. This is indeed what has happened. In order to document these changes so that they may be followed in a meaningful way, I will first describe the foot structure of *Perameles*, which shows the peramelid modifications in a less developed state, and then *Chaeropus* which exhibits advanced stages in the modifications begun in *Perameles*.

In *Perameles* (Fig. 2A) the entocuneiform is enlarged while the mesocuneiform is reduced and loses contact posteriorly with the navicular. The proximal part of the mesocuneiform is supported partly by the entocuneiform and partly by the ectocuneiform which abut in the area of the original naviculo-mesocuneiform contact. Metatarsal four is supported in part by the cuboid and in part by the ectocuneiform. There is a small flange projecting forward from the medial side of the ectocuneiform supporting the third metatarsal; however, the greater part of the ectocuneiform is incorporated into the support of the fourth metatarsal. In spite of this, the cuboid retains contact with the greatest portion of the fourth metatarsal and all of the fifth metatarsal (Fig. 3A). Accompanying these changes, there is an increase in contact of the astragalus with the navicular. The calcaneo-cuboid contact is reduced in accordance with the reduction of the cuboid.

Macrotis exhibits a tarsal arrangement intermediate between *Perameles* and *Chaeropus* (see Fig. 2B). On dental differences, *Macrotis* is less closely related to *Perameles* and *Chaeropus* than the latter are to each other (Bensley 1903). However, the tarsal arrangement seen in *Macrotis* is intermediate between *Perameles* and *Chaeropus* and it is this point with which this study is concerned.

In *Chaeropus* (Fig. 2C) the entocuneiform-ectocuneiform contact becomes larger and the mesocuneiform is reduced to a mere vestige. The ectocuneiform assumes a greater role in support of metatarsal four. Metatarsal three loses contact with the ectocuneiform and is supported by a syndesmodial articulation in a small groove on the medial side of the fourth metatarsal.

The ectocuneiform has lost its original function (support of metatarsal three) and is incorporated completely into support of the fourth metatarsal (Fig. 3A). The cuboid retains some support of metatarsal four although the area of contact is further reduced. The cuboid retains support of metatarsal five. The astragalo-navicular contact becomes enlarged, the calcaneo-cuboid contact reduced (Fig. 4). The greater part of the body weight is thus directed to the foot via the astragalus. A portion of the body weight is still carried to the calcaneum. However, the calcaneo-cuboid contact is skewed outward at an angle of 30° so that there is potential for slippage and the value of support is reduced. In addition, a posterior encroachment of the navicular occurs on the proximal side of the cuboid, resulting in transfer of weight from the navicular directly to the cuboid. The astragalus assumes a quadrilateral shape although it lacks a deepened tibial trochlea. The presence of a single sole pad near the end of digit four suggests that contact of the foot with the ground is largely restricted to this area.

DISCUSSION

The changes in tarsal arrangement as exhibited in the series *Perameles*→*Macrotis*→*Chaeropus* has been (1) loss of the mesocuneiform, (2) ectocuneiform shifts role from support of metatarsal three to partial support of metatarsal four, (3) cuboid reduced and shares support of metatarsal four with ectocuneiform, (4) enlargement of astragalo-navicular contact, and (5) reduction of calcaneo-cuboid contact. These changes allow for a great part of the body weight of the animal to be transferred to the distal tarsals, by-passing the calcaneum. Associated with these changes in tarsal rearrangement has been elevation of the heel from the ground, increased allometric growth in metatarsal four in relation to rest of foot, reduction of lateral digits, and restriction of contact of the foot to the anterior end of digit four. The net result has been a functional convergence in the hindlimb mechanics of ungulates and peramelids, with *Chaeropus* exhibiting the ultimate of these specializations in the Peramelidae. It is possible that peramelids were guided by similar selective forces favouring cursorial specializations as occurred in

ungulates (Howell 1944, Lull 1903, Schaeffer 1947).

The hindlimb osteology of peramelids is not totally indicative of a cursorial animal. Jones (1923-25) notes that all peramelids are fossorial in varying degree, although *Macrotis* is the only member that constructs extensive burrows for habitation. Lack of a deepened tibial trochlea and a more rigid contact between the astragalus and calcaneum allows for a great manoeuvrability of the pes which may be associated with this habit. In essence, the structure of the peramelid hindlimb is the result of an evolutionary compromise: the present condition evolving within the limits imposed by the use of the hindlimbs in running and, to a lesser extent, burrowing (by analogy with Vaughan 1970 dealing with a similar concept in bats).

Although the pes of macropods show a close resemblance to the pes of peramelids (i.e. reduction of lateral digits and increase in length of foot as a result of allometric growth in metatarsal four) the tarsals differ considerably in their arrangement (Fig. 3AB, 5ABC). The body weight of macropods is supported to a great extent by the hindlimbs as reflected in the ricochet (bipedal saltation) mode of progression used by these animals, although the front limbs and tail are used in support and movement while the animal is feeding (Frith and Calaby 1969). Consequently the greater the area of contact of the hind feet with the ground, the greater will be the stability of the animal. This is achieved by the hind feet becoming completely plantigrade. The calcaneum increases in size relative to the astragalus as does the astragalo-calcaneal contact. Contact of the astragalus with the distal tarsals is reduced (Fig. 4D). There is no ectocuneiform-metatarsal four contact. The greater part of the body weight is transferred from the astragalus on to the calcaneum, then to the distal tarsals. These changes are in direct contrast to those seen in peramelids (quadrupeds) and are indicative of the different modes of locomotion incorporated by these two groups.

Although both these groups have adapted differently in their modes of progression (peramelids being cursorial quadrupeds and macropods ricochettal bipeds) they nevertheless show convergent modifications which are regarded as specializations for speed.

Barnett and Napier (1953) note that . . . 'A further example of convergent evolution within the order marsupialia itself is provided by the development, apparently independently (Bensley 1903) of similar specialized modifications in the fibula of the . . . Macropodidae and Peramelidae

. . . ' This convergent specialization involves the tibia and fibula being united inferiorly by a syndesmosis that ranges the extent from one-quarter to one-half of the total length of the tibia. They further note that . . . 'The form and mobility of the fibula in these saltatory marsupials is analagous to that occurring in the Eutherians'.

The arrangement of the tarsal bones in peramelids and macropods is readily derived from that arrangement shown in phalangerids (Fig. 4B). Peramelids have deviated from the phalangerid condition in the relationship between the cuboid, ectocuneiform, and metatarsal four as discussed earlier. The calcaneum, astragalus and navicular arrangement is essentially unaltered although the contact between the astragalus and navicular becomes larger in the peramelids while the calcaneo-astragalus contact shows relative reduction. *Perameles* exhibits a late stage in this transformation with the ectocuneiform supporting both metatarsal three and four. Both groups are syndactylous. Macropods have deviated from the phalangerid condition in the relationship between the astragalus, navicular, and calcaneum. In macropods the astragalo-calcaneum contact is greatly enlarged while the astragalo-navicular contact is greatly reduced. There has been no change in the relationship between the cuboid, ectocuneiform and metatarsal four as is seen in peramelids. Macropods are also syndactylous. In peramelids, the net result of these changes has resulted in the channelling of the greater part of the body weight along a vector as shown in Fig. 6A; while in macropods the greater part of the body weight passes in a vector as shown in Fig. 6B. The phalangerid tarsal arrangement allows the body weight to be more evenly distributed on to the foot by utilizing both these vectors more equally; the resulting transfer of body weight being directed as shown in Fig. 6C.

The changes exhibited in the macropods and peramelids are the result of the utilization of the fourth digit as the main support digit. The resulting difference between peramelids and macropods, utilizing different vectors of transfer of body weight to digit four, are linked with the quadrupedal mode of progression of peramelids and a bipedal mode of progression of macropods. The result has been a more direct vector for weight transfer on to the main supporting surface of digit four. In peramelids the weight is directed toward the most distal end of digit four, in macropods it is directed more toward the heel.

The derivability of the peramelid and macropod tarsal arrangement from the phalangerid tarsal arrangement suggests that syndactyly need have arisen only once in the Australian marsupials as

opposed to a double origin as proposed by Tate (1948, p. 317). As the peramelid and macropod foot structures are both derivable from a phalangerid type foot it may be concluded that the tarsal-metatarsal arrangement shown in phalangerids is the primitive arrangement and was that arrangement which occurred in the ancestors of these two groups. By further extrapolation it is seen that as the tarsal-metatarsal arrangement is identical in dasyurids and phalangerids, the loss of syndactyly in phalangerids (digits two and three becoming separated) would result in a foot structure identical to that of dasyurids (Fig. 4A). The dasyurids thus show a foot structure from which all modifications occurring in the present-day Australian marsupials could have been derived.

Tarsal bones are also important as basic indicators of various taxonomic ranks. The evolution of the tarsus and subsequent calcaneal alterations have resulted in the introduction of basic ordinal characters in artiodactyls (Schaeffer 1947) and perissodactyls (Radinsky 1966). Robinette and Stains (1970) have shown that a study of the calcanea of pinnipeds may give some indication of the relationships among members of the different families and possibly some indication of ancestry. Similar results establishing the importance of tarsal bones in taxonomy have been reported by Stains (1959, 1962) and Romankowowa (1963). Although most of these workers have based taxonomic importance on the astragalus and calcaneum, there is little reason why a gross rearrangement of the distal tarsals should not receive a similar consideration. Of the Australian marsupials, the ectocuneiform-metatarsal four contact is a unique morphological entity found only in the peramelids (Gregory 1951, Fig. 18, 20 has erroneously shown the wombat with an ectocuneiform-metatarsal four contact).

Of the Australian marsupials, the Peramelidae are polyprotodont and syndactylous while all other Australian polyprotodonts are didactylous and the diprotodonts are syndactylous (see Jones 1923-25, Ride 1964, Tate 1948). The presence of both polyprotodonty and syndactyly in peramelids has caused considerable difficulties in the higher taxonomic position of this group (see Ride 1962, 1964). Perhaps the ectocuneiform-metatarsal four contact is the diagnostic character which truly sets peramelids apart from their contemporary relatives, and that such a difference may warrant taxonomic consideration.

SUMMARY

In peramelids the greater part of the body weight is transferred to the foot via a vector passing from the tibia-astragalus-navicular-ectocunei-

form-metatarsal four. This has resulted in an alteration in the relationships between the cuboid, ectocuneiform and metatarsal four from that arrangement of these bones seen in the foot structure of a proposed phalangerid ancestor. This vector of transfer of body weight is linked with a quadrupedal mode of locomotion. The resultant ectocuneiform-metatarsal four contact is unique to the Peramelidae among the Australian marsupials; it has been suggested that such differences may warrant taxonomic consideration. Ungulates exhibit similar modifications regarding weight transfer and the result has been a functional convergence in the hindlimb mechanics between these two groups.

In macropods the greater part of the body weight is transferred to the foot in a vector via the tibia-astragalus-calcaneum-cuboid-metatarsal four. This vector of weight transfer is linked with a ricochet (bipedal saltation) mode of locomotion. The main alterations from an ancestral phalangerid tarsal arrangement are seen in the relationship between the astragalus, navicular, and calcaneum.

The various changes in weight transfer as seen in macropods and peramelids have resulted from the antecedent development of syndactyly of digits two and three on the hind foot with digit four becoming the main supporting digit. In Eutherians, perissodactyls utilize digit three as the main support digit and in artiodactyls it is digits three and four. In peramelids, tarsal rearrangement was necessary before the body weight could pass to the distal tarsals, by-passing to a great extent the calcaneum as does occur in ungulates.

As the peramelid and macropod foot structures are both derivable from a phalangerid foot structure, it is suggested that syndactyly need have arisen only once in the Australian marsupials. The acquisition of syndactyly in dasyurids would result in a foot structure identical to a phalangerid foot, save for relative differences in digit size. It is thus proposed that the foot structure as seen in dasyurids may have been that condition seen in the ancestors of all Australian marsupials. The evolution of the various modifications in foot structure in Australian marsupials has probably progressed in a line from dasyurids to phalangerids, with the latter branching and giving rise independently to peramelids and macropods (see Fig. 4 of this paper; and Goodrich 1935, p. 177).

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EXPLANATION OF TEXT-FIGURES 1-6

- FIG. 1—Mammalian pes (right). A, hypothetical mammalian ancestor; B, horse (Perissodactyl); and C, Pudu (Artiodactyl): modified from Hildebrand, 1960. Abbreviations: **cal**, calcaneum; **me**, mesocuneiform; **as**, astragalus; **eu**, cuboid; **ee**, ectocuneiform; **en**, entocuneiform; **nav**, navicular; digits I, II, III, IV, V.
- FIG. 2—Pes of peramelids (right). A, *Perameles*; B, *Macrotis*; and C, *Chaeropus*. Note that associated reduction of digits I, II, III and V is accompanied by elongation of digit IV, largely the result of allometric growth in metatarsal IV. For abbreviations see Fig. 1.
- FIG. 3—Proximal end of right metatarsals of A, *Macrotis* and B, *Macropus* showing contact surfaces with tarsals. Note the large contact area of the ectocuneiform with metatarsal IV in *Macrotis*. In *Macropus* metatarsal IV contacts only with the cuboid. For abbreviations see Fig. 1.
- FIG. 4—Dorsal view of tarsals (astragalus removed) showing contact of astragalus with calcaneum and navicular (vertical hatch). The illustrations: A, dasyurid (*Dasyurus*); B, phalangerid (*Trichosurus*); C, peramelid (*Perameles*); and D, macropod (*Macropus*) are arranged diagrammatically in probable order of derivation. A and B are similar with regard to tarsal arrangement as well as showing a similar division of contact of the astragalus between the calcaneum and navicular. Note that in C (*Perameles*) the contact of the astragalus with the navicular is large while in D (*Macropus*) this contact is small while the contact of the astragalus with the calcaneum is greater in D (*Macropus*) and smaller in C (*Perameles*). These differences represent extremes which have deviated greatly from the more even distribution of these contacts (astragalus-navicular, astragalus-calcaneum) as seen in B (*Trichosurus*). Note enroachment of navicular on to proximal end of the cuboid in C (*Perameles*).
- FIG. 5—Pes of macropods (right). A, *Thylogale*; B, *Macropus*; and C, *Megaleia*. For abbreviations see Fig. 1.
- FIG. 6—Diagrammatic representation showing the force vector along which the body weight is transferred to the supporting digit(s) in A, peramelids; B, macropods; and C, phalangerids. For explanation see text.

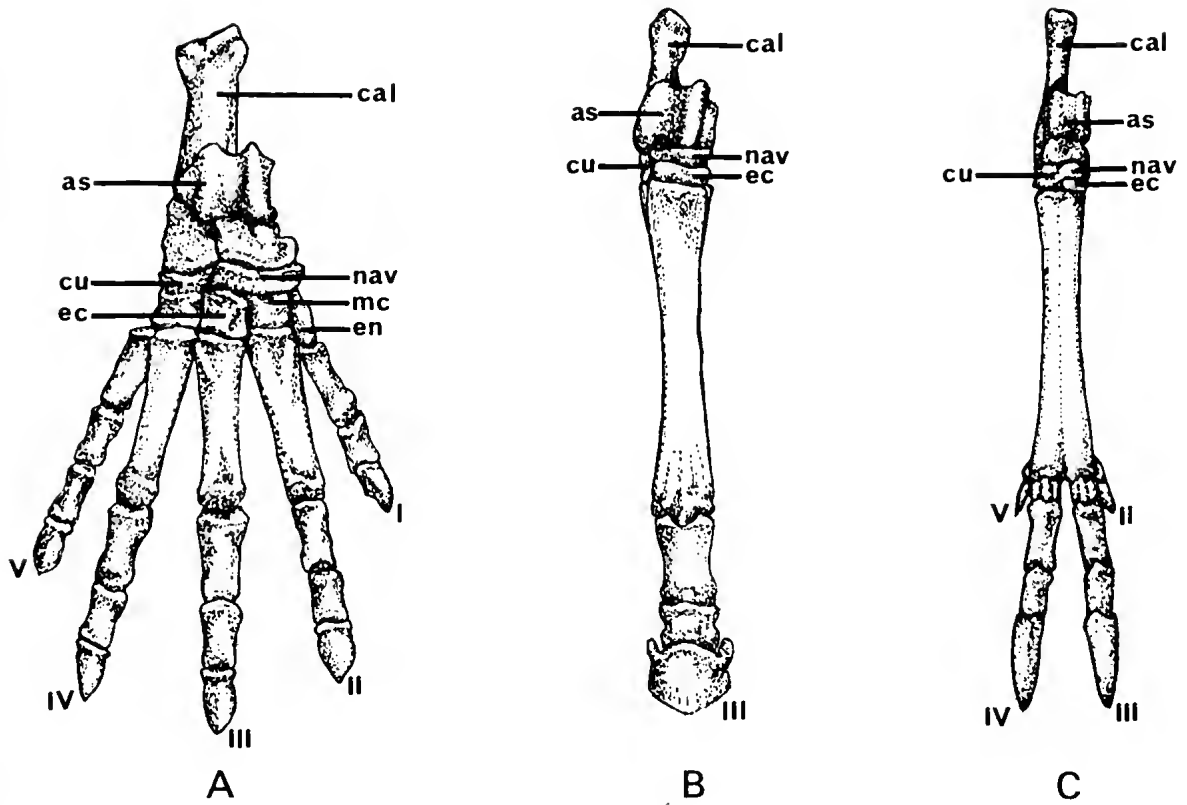


FIG. 1

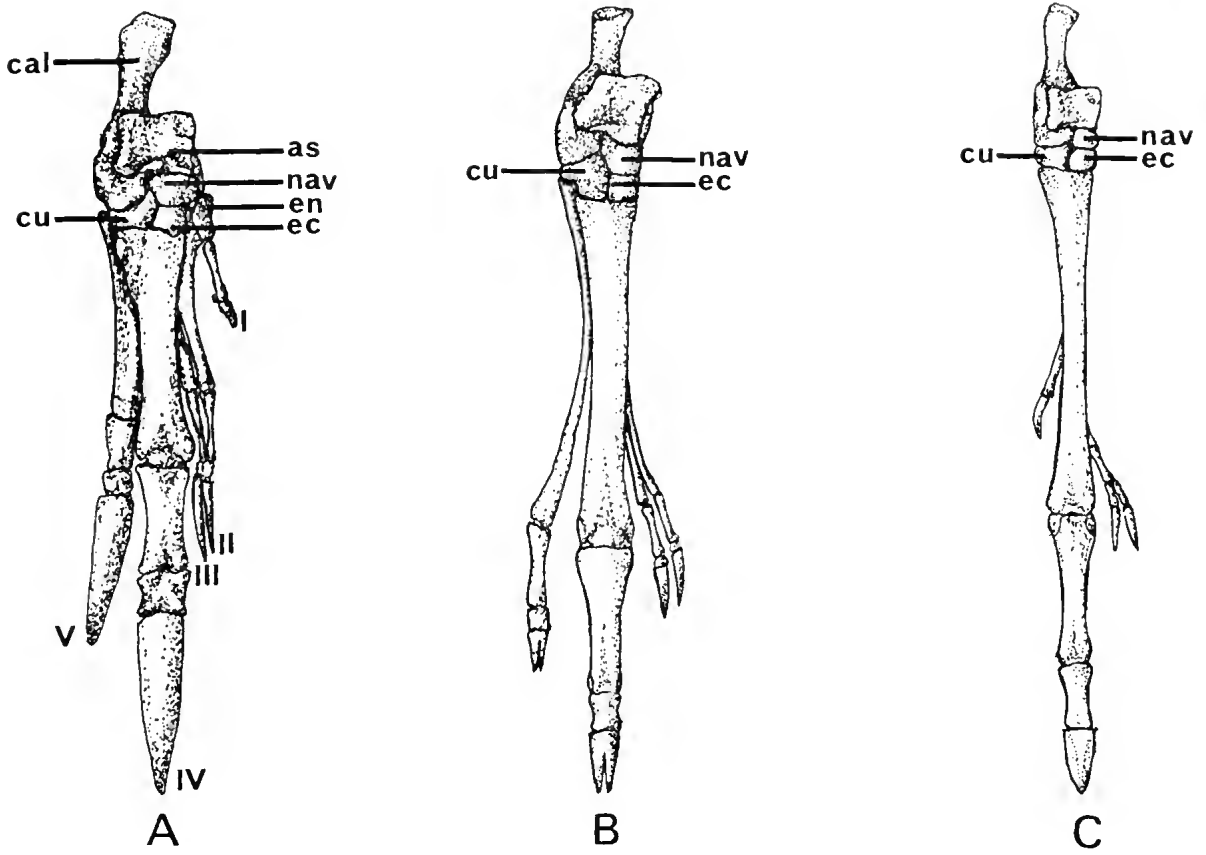


FIG. 2

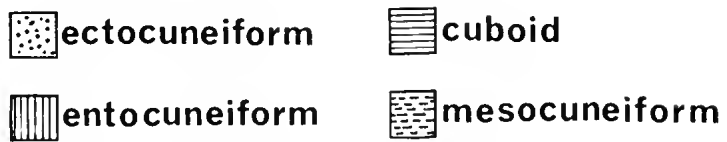
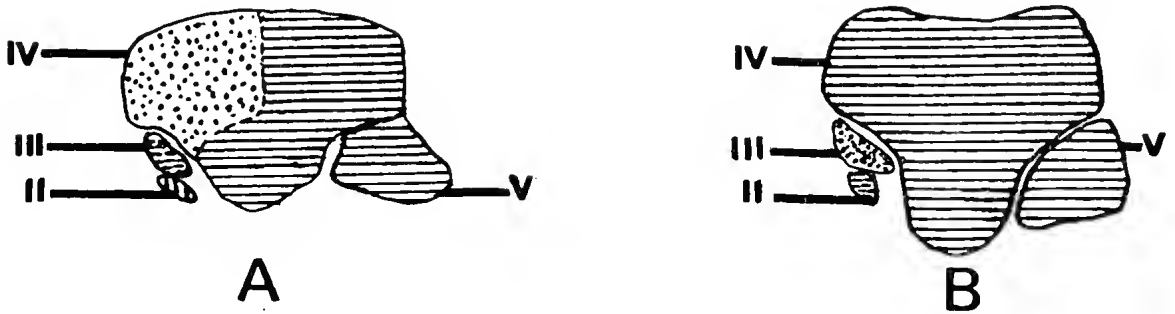


FIG. 3

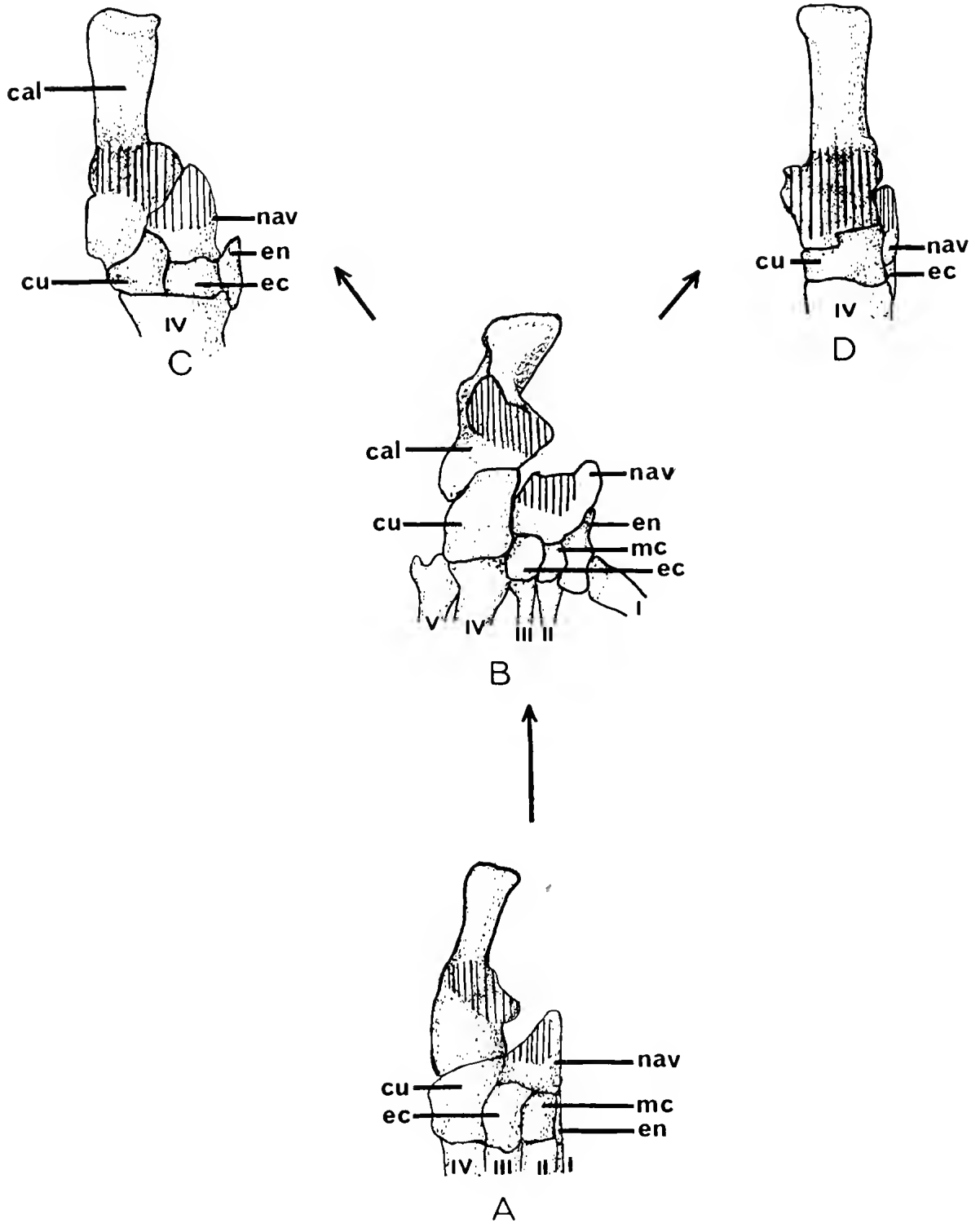


FIG. 4

POTASSIUM-ARGON AGES ON THE NEWER VOLCANICS OF VICTORIA

By AZIZ-UR-RAHMAN* AND IAN McDougall*

ABSTRACT: Fourteen samples of lavas from ten scattered localities in the Newer Volcanics of Victoria give K-Ar ages that range from 1.6 to 4.2 m.y. These results confirm that the volcanism occurred during the Pliocene and Quaternary. In conjunction with palaeomagnetic data previously obtained the results emphasize that the geomagnetic time scale is quite well defined for the last 4 m.y.

A basalt from near Bacchus Marsh has a measured age of 4.03 m.y. This age is of particular significance because Fenner has shown that substantial movement has occurred on the nearby Rowsley Fault subsequent to the eruption of the basalt which has been dated.

Lavas in the ancestral Barwon and Moorabool River valleys of the Geelong area are about 2.1 m.y. old; as these basalts have been warped the latest tectonic activity in the region must be younger than very Late Pliocene.

The vertebrate *Glaucodon ballaratensis* described from the Smeaton area is probably younger than the age of 2.1 m.y. obtained on a basalt thought to underlie the sediments in which the fossil was found.

Volcanic rocks of the Grant Volcano, south of Portland, are at least 2.76 m.y. old (Late Pliocene). Previously these rocks were regarded as Lower Pleistocene.

INTRODUCTION

The Newer Volcanics of Victoria crop out over an area of about 25,000 km², mainly to the west of Melbourne (Fig. 1). The lavas, which range from a few metres to 150 m in thickness, were erupted from numerous vents, and are mainly olivine basalts (Edwards 1938). The Newer Volcanics are entirely subaerial and overlie marine sediments ranging up to Late Pliocene in age. Geomorphological and radiocarbon dating evidence indicates that eruptions continued into Recent times (Gill 1964). Previous K-Ar dating of the Newer Volcanics shows that volcanism commenced at least 4.5 m.y. ago in the Pliocene (McDougall *et al.* 1966).

In this paper we present 14 new K-Ar ages on samples from the Newer Volcanics; these provide further confirmation that the eruptions occurred in the Pliocene and Quaternary. Data on basalts from the Geelong and Portland areas contribute to knowledge on the geological history of these regions. The age data together with palaeomagnetic measurements on the same rocks are of some importance in relation to the geomagnetic polarity time scale.

PALAEOMAGNETIC INVESTIGATIONS

Following on the earlier studies of Irving and Green (1957) and Green and Irving (1958), Aziz-ur-Rahman (1971) carried out more detailed palaeomagnetic work on samples of the Newer Volcanics directed primarily toward palaeosecular variation. At least three oriented samples were collected from each site. Alternating field demagnetization was used to remove secondary components of magnetization from each sample. The mean direction of magnetization obtained from all samples closely approximates that of the present rotation axis of the earth. Of the 8 sites from which samples were dated in this study, 4 sites showed normal polarity and 4 showed reversed polarity.

K-Ar DATING

The samples used in the present study were selected from those collected for the investigation reported in Aziz-ur-Rahman (1971). In addition several samples from earlier collections were used. The specimens chosen were from sites not previously dated by McDougall, Allsopp and Chama-laun (1966); the selection was made after

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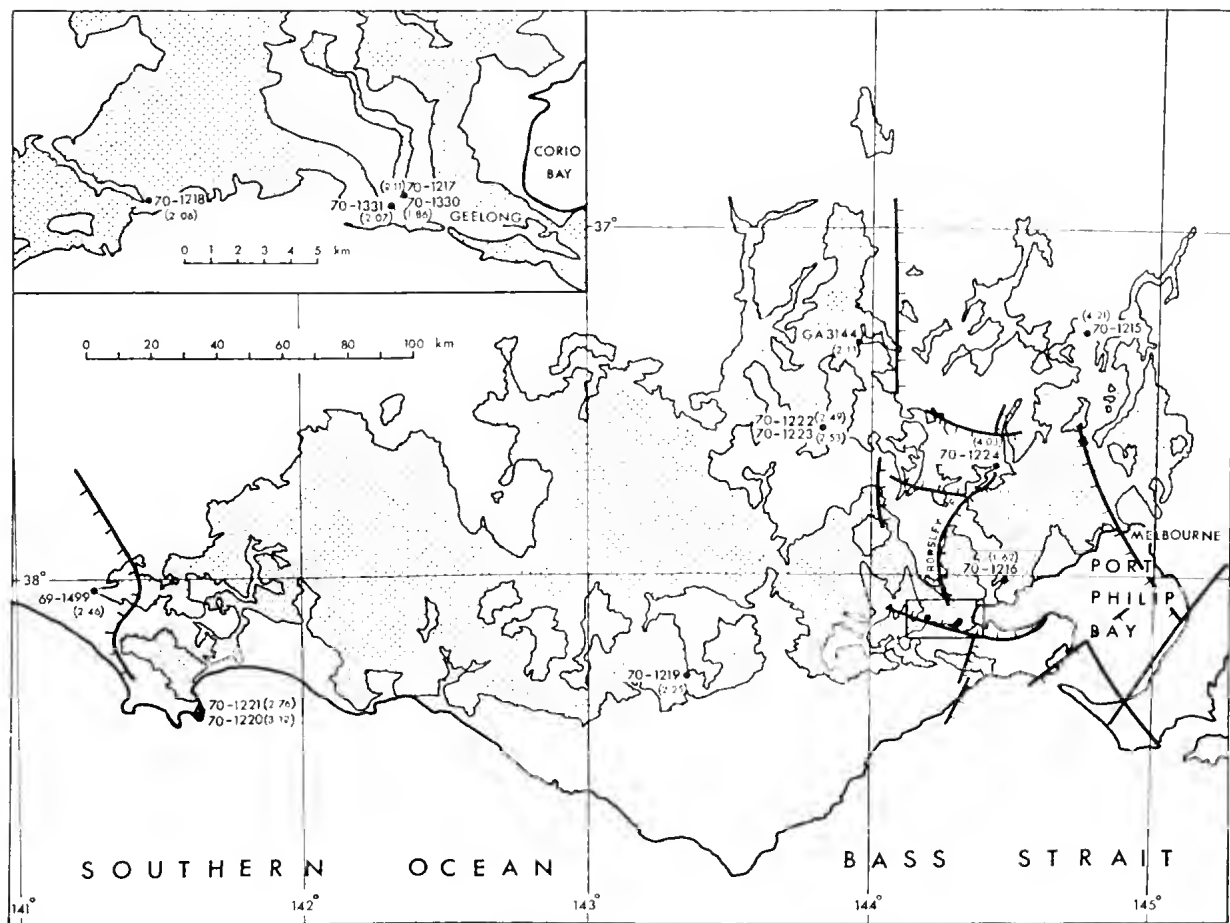


FIG. 1.—Map of Victoria showing the distribution of Newer Volcanics and the localities of the samples used in this study. Figures within brackets indicate the calculated age in million years.

examination of numerous thin sections. Only those samples were used that showed little or no alteration to minimize the possibility of loss of radiogenic argon after crystallization. However some of the samples contained glass or fine grained or imperfectly crystallized intersertal material which may be prone to argon leakage. As a check on such behaviour in some cases two or more different samples from the same locality were measured. A brief petrographic description together with detailed locality information is given in the appendix.

Techniques of measurement used in this study were given previously (McDougall 1966); argon was determined by isotope dilution and potassium by flame photometry. The weight of sample for individual argon extractions ranged from 12 to 30 g. The constants used in the calculation of ages are: $\lambda_e = 0.585 \times 10^{-10} \text{ yr}^{-1}$, $\lambda_\beta = 4.72 \times 10^{-10} \text{ yr}^{-1}$ and $K^{40} = 1.19 \times 10^{-2} \text{ atom per}$

cent. Results are listed in Table 1; errors quoted are one standard deviation based upon the internal precision of the measurements in each determination (McDougall *et al.* 1969). The magnetic polarity of each lava sampled is also given in Table 1 from Aziz-ur-Rahman (1971).

RESULTS

The ages measured on the 14 samples from 10 widely scattered localities (Fig. 1) range from 4.2 to 1.6 m.y. This spread of ages falls completely within the age range of 4.5 to 0.57 m.y. previously reported by McDougall, Allsopp and Chamalaun (1966) for lavas from 12 different localities throughout the Newer Volcanic province. Thus the new results strengthen the view that eruption of the Newer Volcanics occurred mainly in the Pliocene and Quaternary, as the Pliocene-Miocene boundary is thought to have an age of about 5.5 m.y. (Berggren 1969) and the

TABLE 1
Potassium-Argon Ages on Lavas of the Newer Volcanics of Victoria

| Sample number | Field number | Polarity | Potassium % | Rad. Ar $\times 10^{-5}$ cc NTP/g | Rad. Ar $\frac{^{40}\text{Ar} \times 100}{\text{Total Ar}}$ (%) | Calculated age (m.y.) \pm S.D. | Locality |
|---------------|--------------|----------|----------------|-----------------------------------|---|------------------------------------|---|
| 70-1216 | AV54 | R | 0.972 0.979 | 0.632 | 21.4 | 1.62 \pm 0.03 | 20 km S-W of Werribee |
| 70-1217 | AV60 | R | 0.926 0.931 | 0.781 | 58.2 | 2.11 \pm 0.02 | Geelong Quarries Ltd., Fyansford, Geelong |
| 70-1330 | UV47 | R | 0.925 0.926 | 0.688 | 31.2 | 1.86 \pm 0.02 | Mobile quarry, Fyansford, Geelong |
| 70-1331 | UV50 | R | 0.906 0.915 | 0.753 | 35.0 | 2.07 \pm 0.02 | Fyansford quarry, Fyansford, Geelong |
| 70-1218 | AV71 | R | 1.025 1.016 | 0.823 0.856 | 49.6 55.9 | 2.02 \pm 0.02 2.10 \pm 0.02 | Pollocksford, 10 km west of Geelong |
| 70-1219 | AV77 | R | 1.076 1.077 | 0.967 | 58.6 | 2.25 \pm 0.03 | Armytage quarry, Armytage |
| 70-1222 | AV101 | N | 1.038 1.033 | 1.029 | 51.4 | 2.49 \pm 0.03 | Council quarry, Alfredton, Ballarat |
| 70-1223 | AV105 | N | 1.076 1.069 | 1.084 | 59.1 | 2.53 \pm 0.03 | |
| 69-1199 | WU11 | - | 1.288 1.311 | 1.270 | 31.9 | 2.46 \pm 0.03 | 11 km south of Dartmoor, about 1 km east of Glencelg River |
| 70-1220 | AV87 | N | 0.793 0.805 | 0.997 | 17.0 | 3.12 \pm 0.04 | Portland Harbour Trust Quarries, south of Portland |
| 70-1221 | AV89 | N | 0.974 0.971 | 1.071 | 33.6 | 2.76 \pm 0.03 | " " " " |
| 70-1224 | AV112 | N | 1.915 1.918 | 3.087 | 75.9 | 4.03 \pm 0.04 | 1 km S-W of Bacchus Marsh |
| 70-1215 | AV45 | N | 3.029 3.046 | 5.107 | 78.6 | 4.21 \pm 0.05 | Melbourne Hill Quarry, near Lancefield |
| GA-3144 | - | - | 1.971 1.971 | 1.662 | 51.7 | 2.11 \pm 0.03 | West Berry Consols Mine, about 2 km west of Sreaton |

Pliocene-Pleistocene boundary an age of about 1.7 to 1.8 m.y., accepting the base of the Italian Calabrian Stage as the most reasonable definition for the base of the Pleistocene (Berggren *et al.* 1967, Phillips *et al.* 1968, McDougall and Stipp 1968).

In those cases where more than one sample was dated from an individual lava flow the agreement between the ages ranges from excellent (70-1222 and 70-1223, Ballarat) to quite marked disagreement, with differences well outside experimental error. In the Geelong area at Fyansford three samples were dated from a single flow in the Moorabool Valley and the measured ages found were 1.86 m.y. (70-1330), 2.07 m.y. (70-1217) and 2.11 m.y. (70-1331). The specimens from this lava contain about 20 per cent of glass charged with microlites and the results suggest that significant loss of radiogenic argon may have occurred at least from sample 70-1330. The two concordant ages at about 2.1 m.y. may record the time of eruption of the lava but nevertheless this should be regarded as a minimum age. Similarly the two samples from the Portland area differ considerably in their measured ages. The potassium contents of the two samples are considerably different from one another so that it is likely that the specimens were collected from two distinct flows or intrusions that may be of different age. Although the samples are virtually holocrystalline they both show incipient alteration and minor development of mineraloids in voids; thus the ages must be regarded as minima. The remaining samples dated contain small but variable amounts of poorly crystallized intersertal feldspathic material or glass and show ubiquitous partial iddingsitization of olivine; the ages determined probably are a good approximation to the time of crystallization of the lavas.

GEOMAGNETIC POLARITY TIME SCALE

The polarity time scale for the last 4 m.y. of geological time is now well documented (McDougall and Chamalaun 1966; Cox, Doell and Dalrymple 1968; Cox 1969; Grommé and Hay 1971). The new results from Victoria are plotted against the presently accepted configuration of the time scale in Fig. 2 together with previous data on the Newer Volcanics.

The results from the 8 new sites (4 normal, 4 reversed) all are consistent with the time scale. Four of the dated sites fall within the lower part of the Matuyama Reversed Epoch and show reversed polarity; hence none of the samples falls within the normal polarity events of short duration that are recognized in this epoch. Two of

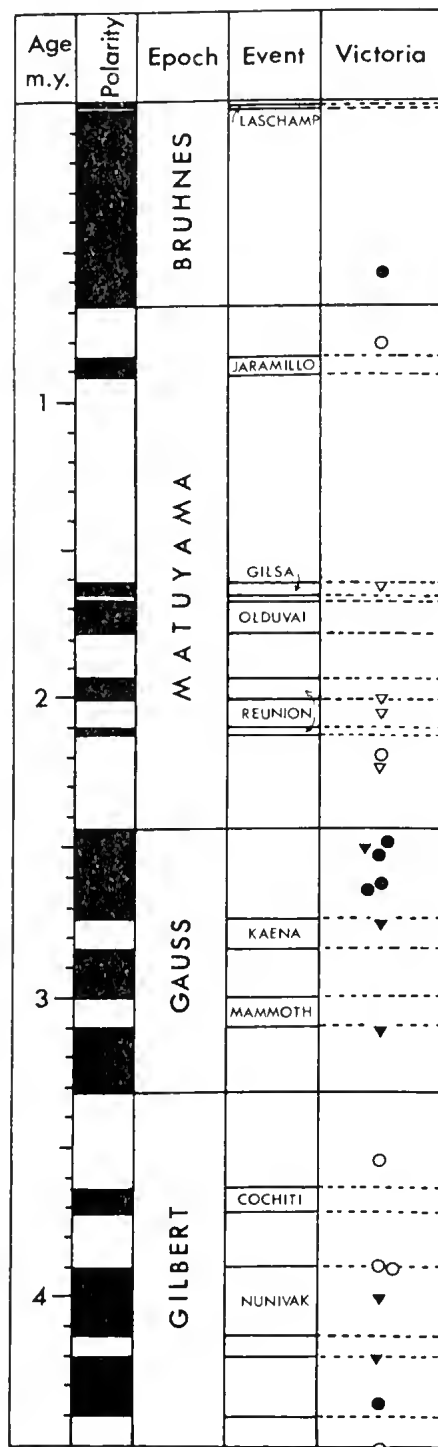


FIG. 2—Diagram showing the magnetic polarity and the age for the Newer Volcanics of Victoria. The polarity time-scale is based on Cox (1969) and is modified for Olduvai and Réunion events according to Grommé and Hay (1971). Circular symbols represent the data from McDougall, Allsop and Chamalaun (1966), while the triangles are based on the present study. Filled symbol normal polarity, open symbol reversed polarity.

the lavas with normal polarity belong to the Gauss Normal Epoch and the remaining two fall within two of the normal events in the Gilbert Reversed Epoch. The consistency of these data serves to emphasize that the geomagnetic polarity time scale for the last 4 m.y. is now quite well defined.

DATA FROM THE GEELONG AND BACCHUS MARSH AREAS

Geelong lies near the southern margin of outcrop of the Newer Volcanics and in a region where the pre-basaltic geology is well known (Singleton 1941; Coulson 1938; Bowler 1961, 1963; Spencer-Jones 1967). The basement consists of Palaeozoic and Mesozoic rocks upon which a thickness of up to 100 m of mainly marine sediments was deposited from the Late Oligocene into the Late Cenozoic. The youngest pre-basaltic sediments are the Moorabool Viaduct Sands of Bowler (1963); this formation contains marine faunas of supposed Kalimnan and Werrikoian ages (Singleton 1941). However T. A. Darragh (pers. comm.) has re-examined the molluscan fauna from this formation in the Moorabool River area and regards the age as Cheltenhamian (Upper Miocene). As shown by Coulson (1938) and Bowler (1961) the area became emergent and a drainage system developed into which basalts of the Newer Volcanics flowed and spread out over the surrounding plains. Rivers were displaced laterally and proceeded to re-excavate valleys which themselves were subsequently filled by more basalt; since that time the drainage has again re-established itself by lateral migration.

An excellent example of lava that partly fills a younger valley is the basalt that occupies the ancestral Moorabool River Valley between Viaduct and Fyansford (Bowler 1961); the flow is up to 50 m thick. This lava has been extensively quarried and three samples were collected from such quarries near Fyansford (70-1217; 70-1330; 70-1331). As previously discussed two of the samples give concordant ages of 2.07 and 2.11 m.y. whereas the third sample gave a somewhat younger age of 1.86 m.y., presumably because of loss of argon. The best estimate of age of eruption is therefore given as 2.09 m.y. This age is Late Pliocene as the Pliocene-Pleistocene boundary has an age of about 1.7 to 1.8 m.y. as discussed above.

Another basalt was dated from Pollocksford, about 10 km west of Geelong adjacent to the Barwon River. Bowler (1961) showed that the basalts here are filling the ancestral Barwon River which joins the Moorabool River just south of Fyansford. The measured age of 2.06 m.y. for the Pollocksford basalt is indistinguishable from that

on the basalt in the Moorabool River Valley; petrographically the samples from both areas show marked similarities as all are characterized by abundant glass with microlites. The measured ages, petrography, and geomorphology are mutually consistent and strongly suggest that these young valley filling lavas were erupted at the same time, possibly even from the same source. Coulson (1938) and Bowler (1961) clearly demonstrated that after eruption of these young basalts warping and faulting took place locally with displacements of up to 70 m. The faulting therefore occurred in the latest Pliocene or in Pleistocene times. Fenner (1918) and Bowler (1966) showed that the faulting in the Geelong area forms part of a much more extensive system of faults which have controlled the development of a large depression partly occupied by Port Phillip Bay.

The western boundary of the Port Phillip Sunkland is marked by the Rowsley Fault which was described in detail by Fenner (1918). This major fault (Fig. 1) has an approximately northerly strike and extends from near Geelong to north of Bacchus Marsh over a distance of more than 50 km. Fenner (1918) estimated that the average throw on the Rowsley Fault is about 250 m west side up. He showed that much of this movement occurred subsequent to the eruption of the Newer Volcanics of the Bacchus Marsh area. Thus the age of 4.03 m.y. on sample 71-1224 from a lava close to Bacchus Marsh on the downthrown side of the fault gives an older limit to the age of the Rowsley Fault, which therefore must be Pliocene or younger. The age results from the Geelong and Bacchus Marsh basalts provide strong evidence that there has been significant movement on the faults bounding the Port Phillip Sunkland in Late Pliocene or younger times as previously suggested by many workers.

DATA FROM THE PORTLAND AREA

The geology of the Portland area was described in considerable detail by Boutakoff (1963) who emphasized its importance particularly in relation to the Pleistocene Period and fluctuations in sea level in response to glaciation.

Two basaltic samples were dated in the present study from the Portland Harbour Trust Quarry on the east side of Cape Sir William Grant, 6.5 km south of Portland. Our specimens were obtained from what Boutakoff (1963) describes as a plug complex that occupies a volcanic centre between the two volcanic subsidence calderas which are postulated to underlie Nelson and Grant Bays. Boutakoff (1963) included the basaltic rocks of Cape Sir William Grant in his Second Phase of

Volcanism which he assigned (p. 31) to the Lower Pleistocene for reasons outlined in the following. Just to the north of Portland Boutakoff (1963) mapped Second Phase basalts overlying the Werrikoo and Maretimo Members of the Whalers Bluff Formation. To the west of Portland in the Dartmoor area the Crawford Member of the Whalers Bluff Formation crops out in what is regarded as a geometrically equivalent position to the basalts overlying the Werrikoo Member at Portland. The Crawford Member contains *Pecten (Notovola) meridionalis* which is thought to be indicative of cool waters; Boutakoff (1963) therefore used this as a marker for the beginnings of the Pleistocene, following Singleton (1941). Thus the age of the basalts of the Portland area are of some importance in relation to the Pleistocene as presently recognized in Victoria. Unfortunately no age data are available on basalts directly overlying the Werrikoo Member at Portland but as these basalts are thought by Boutakoff (1963) to be time equivalents with those of Cape Sir William Grant results on the latter are also of significance.

The two basaltic rocks from Cape Sir William Grant give measured ages of 3.12 m.y. (70-1220) and 2.76 m.y. (70-1221), establishing that the volcanism occurred at least 2.76 m.y. ago. This age is regarded as Late Pliocene on the basis that the Pleistocene began about 1.7 to 1.8 m.y. ago as previously mentioned. How can the Pliocene age suggested from the dating of these basalts be reconciled with the lower Pleistocene age favoured by Boutakoff (1963)? One alternative is that the basalts in the Grant and Nelson volcanoes are older than those overlying the Werrikoo Member at Portland. Another alternative is that the basalts of both areas are of the same age, as Boutakoff (1963) suggests, in which case the disagreement on their age may well be related to definition of the Pleistocene. It is implicit in Boutakoff's writings that the beginning of the Pleistocene coincides with the first marked climatic cooling in the Late Cenozoic. The difficulties of using the criterion of cooling to establish the beginning of the Pleistocene were emphasized by McDougall and Stipp (1968). There is now strong evidence that cooling and glaciation occurred well back into the Late Cenozoic (Stipp *et al.* 1967, Curry 1966, McDougall and Wensink 1966, Armstrong *et al.* 1968) and Denton and Armstrong (1969) showed that some glacial deposits in Alaska are more than 10 m.y. old. Consequently, as previously mentioned, many workers have preferred to return to a stratigraphic definition for the beginning of the Pleistocene. The most commonly accepted definition takes the base of the Calabrian Stage in Italy as the base

of the Pleistocene, the age of which is about 1.7 to 1.8 m.y. Therefore it is possible that the climatic cooling indicated by the fossils contained within the Crawford Member of the Whalers Bluff Formation relate to a time earlier than the beginning of the Pleistocene if the stratigraphic definition for the base of this Period is accepted.

The basaltic rocks of the Grant and Nelson Volcanoes to the south of Portland have developed on them an extensive erosion surface at 27 to 30 m above present sea level according to Boutakoff (1963). Boutakoff argues that this erosion surface is the result of marine planation at a time when sea level was considerably higher than at present, as he found no evidence for tectonic uplift. Boutakoff (1963) suggests that the planation occurred during the Mindel/Riss interglacial which is thought to have been about 150,000 years ago (Shotton 1967). Our K-Ar results on the Grant basalts show that the erosion surface developed subsequent to 2.76 m.y. ago; therefore it is quite possible that the development of the surface occurred considerably earlier than the Mindel/Riss interglacial. Unconformably overlying the erosion surface are the thick calcareous aeolianites of the Bridgewater Formation; this formation may likewise be much older than previously thought, and may span a much greater time than previously suggested.

BALLARAT AREA

About 25 km north of Ballarat in the vicinity of Smeaton a sample of basalt from the West Berry Consols Mine No. 1 Bore was dated and gave an age of 2.11 m.y., Late Pliocene. About 4.2 km north of this locality a fossil marsupial *Glaucodon ballaratensis* was described by Stirton (1957) from sediments that Gill (1957) regards as younger than the basalts of this area. Thus it seems likely that *Glaucodon* is latest Pliocene or younger in age. In sediments preserved under the basalts of the Smeaton area crocodilian remains have been found (Gill 1961, Gill, pers. comm.), which therefore must be Late Pliocene or older.

About 4 km west of Ballarat at Alfredton two samples probably from the same basalt flow give ages agreeing well at 2.49 and 2.53 m.y. These results together with the Smeaton age suggest that many of the basalts in the Ballarat area are Late Pliocene in age.

SUMMARY AND CONCLUSIONS

Potassium-argon dating on lavas of the Newer Volcanics of Victoria from ten additional localities confirms that the volcanism occurred mainly during the Pliocene and Quaternary. The ages and palaeomagnetic polarity data are all consistent

with the geomagnetic polarity time scale as presently known.

The ages on basaltic rocks from the Geelong, Bacchus Marsh, Portland and Ballarat areas are of particular significance. The youngest lavas in the Geelong area partly fill ancestral valleys of the Barwon and Moorabool Rivers and have an age of about 2.1 m.y. These lavas show some evidence of warping. The 4.03 m.y. age on the basalt from Bacchus Marsh together with the detailed work of Fenner (1918) indicates that considerable movement on the important Rowsley Fault has occurred subsequent to the Middle Pliocene. The age results from Geelong and Bacchus Marsh confirm that tectonic movements, with which the formation of the Port Phillip Sunkland was associated continued into the Late Pliocene or possibly into the Pleistocene.

The age of basaltic rocks of the Portland area is important in relation to the recognition of what rocks in Victoria may belong to the Pleistocene Period. The basaltic rocks comprising Grant Volcano to the south of Portland were erupted at least 2.76 m.y. ago. Accepting that the base of the Calabrian Stage in Italy is presently the best available definition for the beginning of the Pleistocene (with an age of about 1.7 to 1.8 m.y.), then the Grant Volcano rocks are at least as old as Late Pliocene. Boutakoff (1963) regarded these volcanics as of the same age as the basalts overlying the Werrikoo Member of the Whalers Bluff Formation at Portland. If the correlation is correct then the Werrikoo Member is also Pliocene, and the climatic cooling indicated by fossils in the overlying Crawford Member of the Whalers Bluff Formation further to the west may also be of Pliocene age, rather than Pleistocene. It is clearly of considerable importance that further isotopic dating be carried out in the Portland region in order to assist in defining the Pleistocene Period in Victoria and in the elucidation of climatic variations in the Late Cenozoic.

The vertebrate *Glaucodon ballaratensis* appears to be younger than the 2.1 m.y. age found on a basalt from near Smeaton and is therefore Late Pliocene or younger in age.

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- 70-1216 Abandoned quarry 20 km SW. of Werribee. Sample from SE. face of the quarry. Geelong 1:63,360 map, 38° 0'6"S., 144° 28'3"E. Vesicular olivine basalt. Olivine phenocrysts with iddingsite rims set in basaltic holocrystalline, fresh groundmass.
- 70-1217 Geelong Quarries Ltd., Fyansford, Geelong. Sampled from upper terrace of quarry. Geelong 1:63,360 map, 38° 8'45"S., 144° 18'55"E. Olivine basalt. Fresh olivine phenocrysts embedded in a medium grained groundmass of olivine, plagioclase, clinopyroxene with abundant (20%) intersertal opaque glass which contains numerous pyroxene microlites in sheaves. Locally some yellow mineraloid coating vesicles.
- 70-1218 Small abandoned quarry near Pollocksford about 10 km W. of Geelong. Sample from S. face of the quarry. Geelong 1:63,360 map, 38° 8'5"S., 144° 11'6"E. Olivine basalt. Petrographically very similar to 70-1217 but the intersertal glass with microlites is lighter coloured owing to crystallization of iron oxide as discrete grains.
- 70-1219 Armytage quarry, Armytage. S. face of the quarry. Colac 1:63,360 map, 38° 16'6"S., 143° 52'2"E. Olivine basalt. Olivine phenocrysts iddingsitized and set in well crystallized groundmass in which about 5% of poorly crystallized feldspathic material occurs intersertally.

APPENDIX

SAMPLE LOCATION AND
PETROGRAPHIC DESCRIPTION

- 69-1499 About 11 km S. of Dartmoor between Glenelg River and road S. from Dartmoor through Drik Drik. Nelson 1:63,360 map, 38° 01'7"S., 141° 16'7"E. Olivine basalt. Phenocrysts of olivine with marginal alteration to iddingsite occur in fresh basaltic groundmass which contains about 5% of poorly crystallized, intersertal, sometimes turbid feldspathic material. Collected by P. Wellman.
- 70-1215 Melbourne Hill, southern side of abandoned quarry. About 60 km N. of Melbourne, near Lancefield. Lancefield 1:63,360 map, 37° 22'9"S., 144° 34'6"E. Trachyandesite. Phenocrysts of patchy alkali feldspar set in feldspathic finely crystallized groundmass. Iron oxide is abundant together with minor iddingsitized olivine and fresh pyroxene.
- 70-1220 Portland Harbour Trust Quarry, on the E. side of Cape Sir William Grant, about 6.5 km S. of Portland. Sampled from S. wall of the quarry. Portland 1:63,360 map, 38° 24'4"S., 141° 37'7"E. Olivine basalt. Some chloritization of olivine phenocrysts and alteration of groundmass olivine. The rock is virtually holocrystalline in olivine, plagioclase, clinopyroxene and iron oxide but small amount of green mineraloid and slight chloritization along cracks in plagioclase.
- 70-1221 Location as for 70-1220, but from W. flanks of the quarry. Coarse doleritic basalt similar to 70-1220 and also showing some incipient alteration and some mineraloid.
- 70-1222 Council quarry, Alfredton, Ballarat.

- 70-1223 Sampled from W. face of the quarry. Ballarat 1:63,360 map, 37°33·6'S., 143°49·45'E. Olivine basalt. Iddingsitized olivine phenocrysts grading into the groundmass which is virtually holocrystalline and fresh. Minor calcite present.
- 70-1224 Abandoned quarry 1 km SW. of Bacchus Marsh on the southern side of Werribce River. Sampled from N. flank of the quarry. Ballan 1:63,360 map, 37°41·0'S., 144°25·5'E. Olivine basalt. Partly iddingsitized olivine phenocrysts grade into fine grained basaltic groundmass which although well crystallized contains abundant sheaves of pyroxene microlites.
- 70-1330 Mobile Quarry, Fyansford, Geelong. Same locality as 70-1217. Olivine basalt almost identical petrographically to 70-1217 and contains abundant dark glass with microlites.
- 70-1331 Fyansford Quarry, Fyansford, Geelong. Small abandoned quarry opposite Geelong Quarries Ltd. on S. side of the road. Olivine basalt. Similar to 70-1217 and 70-1330 but slightly coarser grained with a few per cent of green mineraloid and perhaps slightly less glass.
- GA 3144 Basalt from depth of 16·8 m in West Berry Consols No. 1 Bore about 2·3 km W. of Smeaton, 25 km N. of Ballarat. Ballarat 1:250,000 map, approx. 37°20·8'S., 143°54·4'E. Well crystallized rock with small phenocrysts of plagioclase and olivine set in a predominantly feldspathic groundmass together with olivine, iron oxide and clinopyroxene. Sample supplied by E. D. Gill.

SHORT COMMUNICATIONS

THE WESTERN PORT EARTHQUAKE OF 6TH JULY 1971

An earthquake occurred in the region of Westernport Bay at approximately 8 a.m. Australian E.S.T. on 7 July 1971 (6 July, G.M.T.). It was felt throughout the Melbourne area, a major part of West Gippsland, and reports were received from 136 km away. The strength of the shock was such that only the initial arrival was recorded accurately on the Toolangi seismograph. In all, nineteen seismograph stations throughout Australia recorded the earthquake but only those within approximately 600 km exhibited clear S-wave arrivals. Damage resulting from the quake was minor and no injuries were reported.

The National Oceanographic and Atmospheric Administration (NOAA) determined the epicentre to be at $38^{\circ}5'S$, $145^{\circ}3'E$, origin time 21h 55m 01.3s (G.M.T.), using reports from 10 stations. Other epicentre determinations were:

(i) $38^{\circ}5'S$, $145^{\circ}1'E$, time 21h 54m 57.9s by the Bureau of Mineral Resources (BMR), Canberra, using 16 stations.

(ii) $38^{\circ}44'S$, $145^{\circ}1'E$, time 21h 54m 58.9s by G. M. Gibson, University of Melbourne, using 19 stations.

An approximate estimate of the magnitude was made according to the method for local shocks outlined by Richter (1958), and revealed a surface wave magnitude of close to 5, from the Canberra seismograph records.

Immediately after the earthquake, questionnaires seeking information on felt intensity were distributed throughout Central Victoria and residents near the epicentre were interviewed. About 150 reports were collected for analysis and a similar number collected by the BMR were also studied.

From the reports, an isoseismal map was drawn (Fig. 1) indicating that the tremor was perceivable over an area of approximately 160 km radius.

The shape of the isoseismals is fairly well defined, but more details of response in the Bellarine Peninsula and La Trobe Valley areas would be useful in studying the relationships between the configuration of faults and the attenuation of earthquake energy as revealed by the isoseismals. The extension of the intensity pattern parallel to the Tyabb and Selwyn Faults indicates that the seismic energy is least attenuated parallel to the fault lines, a trend revealed in previous earthquakes and elsewhere (e.g. Hills 1959, Wilkie 1970).

The plotting of tremor durations on a geological map of the Melbourne area indicated a trend to longer durations of shaking, but not necessarily higher intensities, in suburbs based on sediments.

It is of interest to note that on the day of the earthquake the Moon was full and had significant southerly declination, and was over the Eastern Pacific Ocean. It appears (Bishop 1971) that an increase in earthquake frequency occurs generally for times when the Moon is over this region.

The difference in the epicentre determinations are confined largely to the longitude values, which is probably a reflection of the scarcity of seismic observatories to the east and west of the epicentre. The isoseismal pattern suggests that the epicentre was close to the position $38^{\circ}4'S$, $145^{\circ}2'E$.

Blake (1941) has shown how the focal depth can be estimated from the isoseismal radii. The isoseismals for this earthquake are irregular in shape and the method is therefore limited in accuracy. However, values found using the III, IV and V intensity lines indicate a depth in the range 17-20 km. The depth estimates determined from the seismograph records were: 0-17 km by the BMR, and 19-27 km by G. M. Gibson, suggesting a depth of about 20 km.

An estimate can also be made of the magnitude (Karnik 1961), using the maximum isoseismal intensity and the depth of focus. This method gave a magnitude of 5 for a maximum intensity of VI and a depth of 20 km.

For the provision of data, thanks are due to representatives of the BMR in Canberra, Melbourne, Port Moresby and Mundaring; also to A.N.U., University of Adelaide, Riverview College and University of Tasmania. We are further indebted to many people throughout Victoria who responded to our questionnaire.

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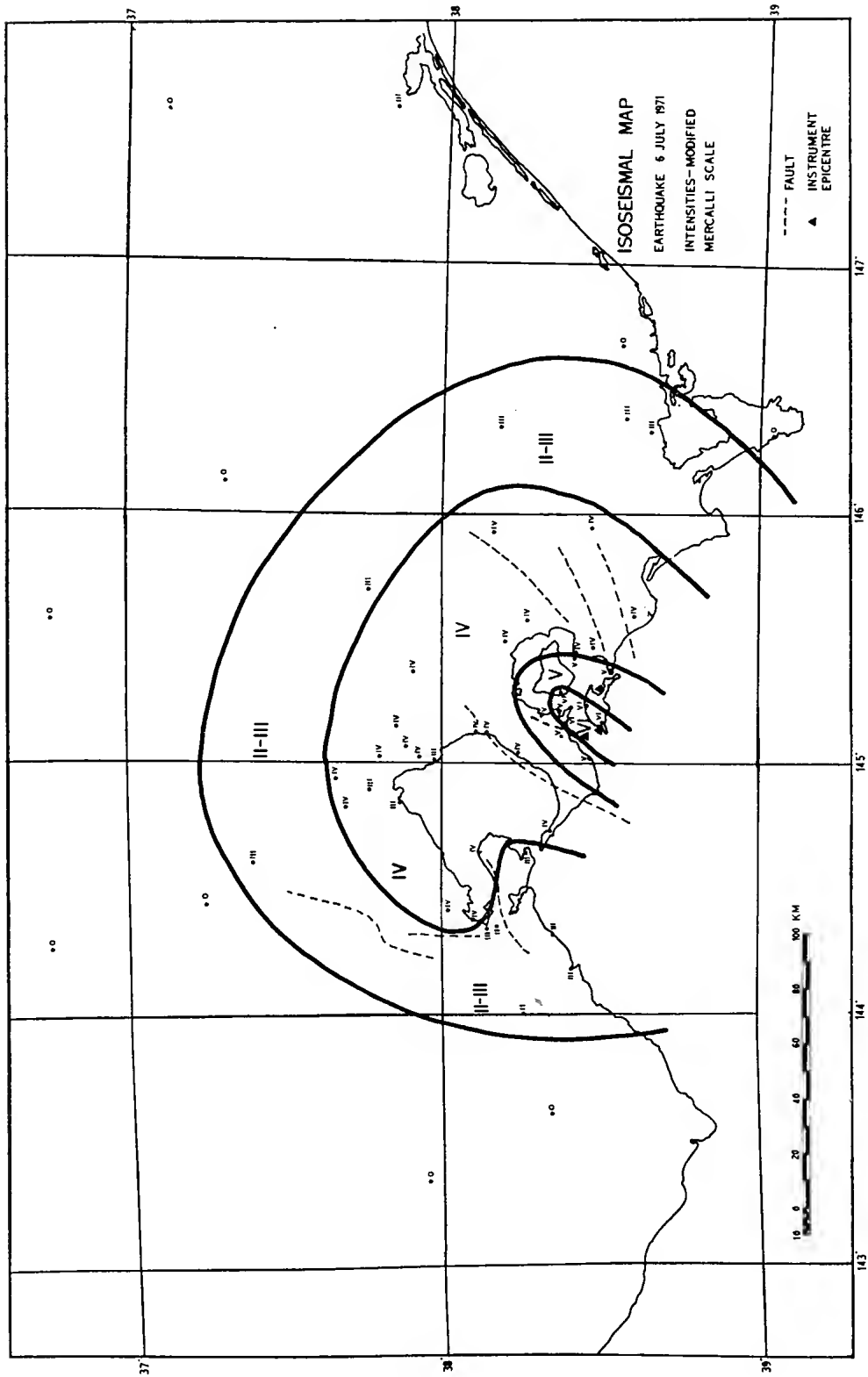


Fig. 1

SCIENTIFIC INVESTIGATION OF BASS STRAIT— A BRIEF HISTORY

By STEPHEN MURRAY-SMITH*

This brief discussion of the history of investigations into Bass Strait can hardly provide more than a gloss to the Bibliography (p. 79) which Jeanette Hope, Ian Norman and I have prepared for this seminar. With Bass Strait we are, I believe, fortunate to have a fairly strictly finite region in which the impact of man's hand, and the effect of man's ideas, can be traced with perhaps unusual definition. I can think of few areas of Bass Strait studies in which the historian and the scientist have not much to offer each other. Thus this bibliography, unusually wide-ranging in its subject headings, is intended, at least in part, as a specific encouragement to interdisciplinary studies. Dr Norman and I wish to record our appreciation of the work of Dr Hope in the preparation of this Bibliography for publication.

Both pure and applied science entered the Bass Strait story from the inception. The practical uses of finding a waterway where none was known are clear. David Collins (1802: 193) described how the saving of a matter of four degrees of latitude in voyages to Port Jackson was but part of the matter: more importantly, the dreaded north-east winds that ships met rounding Cape Pillar were avoided, a week or more could be saved on the passage and, as Collins says, 'the wear and tear of a ship for one week, are objects to most owners, more especially when freighted with convicts by the run'.

The British ships engaged with China found the newly-discovered straits provided them with a welcome alternative to crossing the Indian Ocean on an oblique course, and running the risk of capture by the French squadrons cruising there with malice aforethought (Scott, 1910: 21). Geoffrey Blainey (1966: 81) puts the matter succinctly: 'The home government in 1803 thought the strait was so vital that they had ordered three bases to be made—on the north shore, the south shore, and on King Island . . . Bass Strait seemed so important that it justified an increase in Australian settlements from two to five'.

The practical issues, then, are not in dispute. Perhaps more encouraging were the other motives of the men who discovered Bass Strait. What sent George Bass down into the Strait in that wonderful whale-boat voyage to Westernport which Flinders (1814: cxx) said 'has not perhaps its equal in the annals of maritime history', and what sent both Bass and Flinders back again soon after in the *Norfolk*, was surely not merely problems of navigational convenience, national security, or commercial profit, and not even the orders of Governor Hunter, but an instinct for knowledge which I take it lies at the root of most of our concerns. As Ernest Giles, a later casting from the same mould as Flinders, once said: 'An explorer is an explorer from love, and it is nature, not art that makes him so' (1889: 342).

But, whatever his personal mettle, Flinders was, like Cook (and from whom, through William Bligh, he was in direct line of succession) a master scientist; inventor, as we know, not only of devices such as the Flinders Bar, but above all, through his intellectual brilliance and the almost inhuman perseverance which we are assured goes with such brilliance to denote genius, able to gather, interpret and act on the phenomena with which he came into contact in a profoundly scientific manner. It may be of interest to note here Flinders' view of the importance of 'nautical astronomy'. In a splendid obituary of his cat Trim which I recently came across, Flinders refers to Trim's pleasure in chasing a ball backwards and forwards across the fore-castle of the *Investigator*,

his admiration of the planetary system having induced an habitual passion for every thing round that was in motion. Could Trim have had the benefit of an Orrery, or even of being present at Mr Walker's experiments in natural philosophy, there can be no doubt as to the progress he would have made in the sublimest of sciences. (1809: fol. 3.)

While talking of Flinders it is well to remember the many hydrographers of talent who worked in Bass Strait during the nineteenth century. As inter-

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colonial and overseas trade developed strongly in the 1830's and 1840's, we find J. Lort Stokes and his officers and men of the *Beagle* surveying the Straits between 1839 and 1843, nearly coming to grief in Murray Pass in the Kent Group, and eventually producing Admiralty charts which, as 1695A and 1695B, remain the only set that covers the whole Strait (Lort Stokes, 1846). Although they have, of course, been updated in some respects, they are still on issue under Lort Stokes's name.

The extraordinary development of shipping into Port Phillip after the discovery of gold led to many disasters and near-disasters which not only spurred the building of major lighthouses (though this had already commenced in the 1840's) but led to a succession of increasingly sophisticated surveys of Bass Strait waters, those of H. L. Cox, H. J. Stanley and R. F. Hoskyn being especially noteworthy (Ingleton, 1944: 84 ff.). Nor, too, should we forget the pioneer land surveyors of Bass Strait, such as G. W. Barnard (1826) in the 1820's, and John W. Brown (1887a, 1887b) in the 1880's.

At this point I think we should stop and ask ourselves what the state of organised science was in Australia prior to, say, 1850. Many of the earlier officer class, the kind of men who came out with Governor Phillip, were of course, as gentlemen of the Enlightenment, wedded to the genteel exercise of their talents for observation and note-taking, sketching and commenting on the phenomena of nature. But, as we read in the journal of Phillip's voyage out here,

something more essential than beauty of appearance, and more necessary than philosophical riches, must be sought in a place where the permanent residence of multitudes is to be established ([Phillip], 1789: 52).

An ill-fated Philosophical Society was founded in Sydney in 1821; more importantly, the 'Mechanics' Institute movement, in which applied science was supposed to have a large role to play, was launched in Australia in Hobart Town in 1827. But, of course, there were no universities until 1854, to sponsor or direct research, and, although the Australian Museum in Sydney was in fact founded in 1830, for the first twenty years it did not even have a roof to call its own. Without institutes or centres of some kind, dedicated to systematic teaching, collecting and research, 'science' is of course mere dilettantism; it is for the 'dabbler' as Lady Franklin very honestly called herself at the time she built her lovely little museum in Hobart in 1842 (Fitzpatrick, 1949: 195). W. C. Wentworth (1820: 320-330) had called for the establishment of an agricultural

college, and not a few could, like Archibald Michie (1844), issue a call for serious attention to a planned assault on the physical problems of Australian life, but even such an admirable institution as the Tasmanian Society of Natural History was powerless to proceed beyond polite evenings at Government House where professional gentlemen read their papers on such topics as the blood globules of the platypus (Fitzpatrick, 1949: 198).

It is, however, to this Society that we owe one of the earliest, if not the earliest, scientific paper on a Bass Strait topic: the surgeon and naturalist Joseph Milligan's paper on the 'Shock of an earthquake at Flinders' Island', published in the *Tasmanian Journal of Natural Science* in 1844. (And talking of earthquakes, can some geologist explain to me the 'Cape Barren guns', the noises like booms of distant cannon, which were reported in the 1890's as a common phenomenon in the Furneaux Group? (Gabriel, 1894: 175)). Nor should we forget the early work, at this period and among the Bass Strait islands, of John Gould, not only for his own sake, as a dedicated professional, but because he seems to have set a fashion. According to my own rough census, the 120-odd scientifically-based ornithological papers that have been published about Bass Strait are not that far short of outnumbering those of all other disciplines combined!

The spirit of organised science was not abroad in our land until the 1850's at the earliest, with the establishment of the first two universities, the founding of important museums and, above all, the emigration around the time of the gold-rushes of men who were not only serious amateur scientists—we had had plenty of them before—but were prepared to work collectively and systematically to bring science into a meaningful relationship to public life. In Victoria we think of men like Andrew Clarke and William Blandowski, of Frederick McCoy and of the Rev. Dr. John Bleasdale. Men such as these founded the National Museum, supported the Technological Commission which was set up in 1869, and were behind the schools of mines which were established from 1871.

These were, as I have said, emigrants who gave their minds to the service of their new country. Of necessity they were cadres: by no means were they always field-workers themselves, but they prepared the path for the field-workers.

Of course there had been field-workers in Bass Strait from the very beginning: nearly half a century before even John Gould, the great Brown, '*Botanicorum facile Princeps*', was sailing these waters with Flinders, stuffing his vasculum with plants from the Kent Group, and preparing for

the disappointment of the publication of his *Prodromus* . . . But, essentially, the field workers were to come when the institutions that could train them and support them were effectively established; when the increasing ease and optimism of life could release the time and talents of the many rather than the few; and when it became possible for a significant, even if small, minority to view themselves as Australian, with an Australian orientation to the visual images of their own land, to the nuances of its culture, and to the relationships of its living things.

What I am now saying, of course, is two things: that the amateur has been important, and remains so, in science as in history, in Bass Strait as elsewhere; and that something interesting and important happened about 1880—not only in art and literature, as has often been pointed out, and perhaps even in politics, but especially and essentially in a fundamental commitment to the Australian environment. It was in the 1880's, and also in the 1890's, that some of the most significant field naturalists', ornithological and similar societies were founded throughout Australia. And not only were they founded, but often they flourished more strongly in their first twenty years than they have done since—or such, at least, and pending further research, is my impression. No doubt it was in part a romantic revolt against vulgar materialism and urban squalor, but it was a healthy and necessary one. I see this period, then from 1880 up to 1900, with a carry-over until the first world war, as the essential period of Australian liberalism at its best, working out its social and environmental relations on the basis of its own, indigenous, premises; democratic, because not self-consciously differential, and less concerned than we are with the niceties of the amateur and professional, the academic and the other: less concerned with knowledge capitalism, in fact. It was a hopeful phenomenon, out of which much promise emerged, but it was still-born.

The figures, though based on my very subjective statistical analysis, are, I think, interesting. Before 1870, one is tempted to say before 1880, one can identify hardly more than ten scholarly contributions of any kind to Bass Strait studies. Between 1870 and 1890 we jump to twenty-one such contributions, spread well out over the field, predominantly in the areas of 'natural history' and 'fish'. From 1890 to 1910 we jump to 57 scientific papers, twenty being on birds and twelve, the next highest number, on 'natural history'. It seems more than likely that the great bulk of these fifty-seven papers are the contributions of the amateur

natural historians, often in many ways more interesting, less consciously erudite, and better written than most things scientists can, or are allowed to, write today.

After 1910, however, a variation in the pattern emerges. It is not, of course, unexpected, but it is interesting to see it appear. Suddenly, there are no more papers that can be loosely labelled 'natural history' at all, and even the number of ornithological papers drops sharply. 'Natural history' as a category hardly appears again until after 1950. We have reached, instead, the age of the differentiated specialist and the entry of bureaucracy. The big spurt is in papers on mammals and invertebrates, the latter, like the fishing reports, reflecting in large part the activities of the *Endeavour* researchers: researchers which, for all their patchiness, remain the only co-ordinated, long-term scientific research programme Bass Strait has seen, with the exception of the recent attentions the oil prospectors have paid the area.

Between 1930 and 1950 interest in the Bass Strait region drops right away, and no doubt the war had something to do with this. In the previous twenty years I have identified seventy-two research papers; between 1930 and 1950 only fifty-eight appeared. Most of these were in the area of minerals (excluding oil and gas), but in this period there was clearly a revival of interest in the historical and contemporary anthropology of Bass Strait.

In the twenty years after 1950 there was, of course, a great increase in the number of papers, largely but not entirely reflecting the expansion of academic and CSIRO interests in the area. Compared with the fifty-eight papers published in the twenty years before 1951, the succeeding twenty years have turned up 175 papers; and of these the largest collection, seventy in fact, are bird studies of one kind and other. Here some papers, for instance those on the Cape Barren goose, reflect a developing environmental concern; and the studies on the mutton-bird, also handsomely represented, an economic and social, as well as a strictly scientific, interest.

In this last twenty years twenty-one papers have been published in the mineral field (and I exclude oil and gas from this), while mammals, invertebrates and fish recover strongly from the neglect of the previous twenty years, with thirteen papers in each category. In agriculture there appears to have been no serious work done in Bass Strait whatsoever before the Depression; six published papers, and no doubt many unpublished governmental reports, testify, *inter alia*, to the insensate determination of the authorities in recent years to expand land settlement on some of the islands,

regardless of the mis-use of public funds which has, at times, reached the proportions of a major scandal. One curious and unexpected phenomenon which may be observed in the last twenty years is that virtually nothing serious has been published on the Cape Barren Islanders, past or present, with the exception of the papers of Tindale and Miss Howeler. It can only be assumed that they have slipped even further into the Great White Australian memory-hole than the mainland Aborigines have.

In these attempts at quantificationism which I have put in to satisfy the scientific mind, I have skipped too rapidly over some points I should have taken up in more detail. (And, incidentally, I should have liked to talk about the non-scientific books and articles on Bass Strait which are prominent in our bibliography, and often closely related to scientific interests, but these are outside my brief.)

I should, in talking of the distinguished contribution made to Bass Strait studies in earlier days by the amateur naturalists, have remarked especially on the series of expeditions which commenced in November 1887 with the pioneering trip of the Field Naturalists' Club of Victoria to King Island, under the leadership of A. J. Campbell (Campbell, 1888). It is interesting to reflect, when we think of King Island so soon afterwards being put to the torch in the interests of the land speculators, that Baldwin Spencer, a distinguished member of this early expedition, could write of it as being one of the 'wild uncivilised spots' (1888: 13). Latter-day scientists and field naturalists may also care to reflect on the fact that the government of Victoria lent the F.N.C.V. the steamer *Lady Loch* in order that they might make this excursion (*Argus*, 23 December 1893). The engineer E. D. Atkinson (1890: 156-164) explored, during 1889, other islands in the western group; while in November 1890 a party, led by D. Le Souef, spent eleven days in the Kent Group (1891: 121-131). In 1893 J. Gabriel led a party to the Furneaux Group, where they spent an entertaining and instructive period (1894: 167-184). Fifteen years later Melbourne business and professional men were in the habit of chartering steamers to introduce them, in an educative and responsible way, to the charms and the interests of the islands (e.g. Barrett, 1918: 119 ff.). And then it all stopped.

Realising, as we now do, the tenuousness of the environmental position on and around the islands, the fragility of their ecosystems, I suppose none

of us would want to encourage gadabouting, or should one say 'runabouting'. Yet it is strange how Australians have resolutely turned their backs on the maritime environment which in many ways is so much part of their history, and which in this case, as Professor Warren has pointed out (1969: 109), lies so close to major centres of population.

I should also like to mention briefly, and in the historical context, the 'beach population' of the islands of Bass Strait to which I have already referred in passing: the descendants of the sealers who, in the nineteenth century, built up what appeared to be a relatively strong economic and social group. I refer to this in my present context because, as a scholar has recently demonstrated most interestingly in the *Papers and Proceedings of the Tasmanian Historical Research Association* (Ryan, 1972), historians and others in the nineteenth century used the Bass Strait community as raw material for much quasi-anthropological and quasi-genetic theorising, and this material in itself is now a part of our intellectual history and of joint concern both to the historian of ideas and the social scientist.

There remains a great deal more of mutual interest to the historian and the scientist in the story of Bass Strait. One very attractive subject on which they could collaborate would be, for instance, the development of the Bass Strait fishing industry, such as it is. Why is it possible, for instance, for James Barrett (1918: 148) to say in 1910 that there is no marine biologist in Victoria, that 'our fisheries have never been considered from the scientific standpoint', and that 'and accurate and scientific knowledge of the life and habits of fish' is the 'first requisite', and for Alister Gilmour (1969: 68) to write sixty years later that, 'with respect to fisheries at least', Bass Strait 'is unknown at this stage and cannot be known until detailed studies are carried out in the region'. The study of the historical relationship of man and fish in Bass Strait would surely be of great scientific, as well as social and historical, interest.

In the history of Bass Strait investigations as, I suspect, in other studies of Australian science, we can perhaps very broadly distinguish the period before, say, 1914 as the age of the amateur, and the period since 1914 as the age of the specialist. This still begs a lot of questions. One of these questions would involve the changing role of the amateur, and his relationship to the specialist. Another, perhaps closely linked, would involve the relationship between science as knowledge-seeking,

science as profit-seeking for the private corporations, and science as status-seeking for the government and semi-government corporations. Clearly one of the interesting issues which emerges from this little study, as it would emerge from much more ambitious ones of virtually any area one chose to take, is that the scientist may increasingly be forced to work against his own interests, assuming those interests, in the broadest sense, to be knowledge-based and conservation-oriented. The scientist whose work has been underwriting the exploration of Bass Strait minerals, or assisting in land settlement there, may be seen to be acting against a rational future in terms of resource allocation for the nation or the world, although it may seem hard to blame him as an individual for this.

Of course there has also been an increase of knowledge-based, as well as profit-based and status-based, science in Bass Strait, though it is not always easy to separate these three motives which may sometimes be involved in the one investigation. University-type investigations in Bass Strait, for instance, basically 'knowledge-based', are also clearly linked to the status race in higher education, both as it affects individuals and as it affects institutions.

Perhaps the major criticism of the present position of knowledge-based scientific investigation in Bass Strait that we may make is that it remains poorly co-ordinated, in two important ways. In the first place, the often distinguished contributions of individual workers are carried out randomly, as regards problems, and episodically, as regards long-term linkages. (Dom. Serventy's work, of course, is a notable exception to this latter criticism.) For much of this we can blame the poor showing of the universities in their attention to local problems; and of CSIRO also, though they perhaps have a better excuse. The absence of funds is—as anyone who knows the universities will realise—only a part of the matter.

The second major criticism is that the scientists, despite the fact that only a handful are yet involved in Bass Strait, share the common fault of their breed in being more interested in their own specialisms than in the corollary of those specialisms: the need to ensure, by working through their colleagues, the community and through politics, that their specialisms' habitats survive. I shall go no further here than to remark that it does indeed seem extraordinary that a start has not yet been made with major biological surveys and censuses of Bass Strait based on inter-institutional and inter-disciplinary teams, and utilising if necessary fishing boats, aircraft and portable laboratories. I am aware of the fact that

individual organisations are often hard pressed. I am aware of the unfortunate fact that the region is divided between two States, one of which almost ignored it until money came flowing from its sands, and the other of which has regarded and regards it as little more than a nuisance. But I am also aware of the fact that a multiplicity of institutions—the Australian Conservation Foundation, the universities, CSIRO, the Royal Society, museums, private companies, government departments and so on—are, at least in principle, interested. What is lacking is a catalyst, and it is the absence of that catalyst that I feel regrettable, and avoidable.

Until, then, some such development takes place, we must see Bass Strait science as still caught in its 'middle' period: beyond amateurism, but still well short of true professionalism. Perhaps this Symposium, and perhaps even the Bibliography which is a part of it, will assist the process. And the end of the process I hope will be, and I take it most of us here at this meeting hope will be, the preservation of Bass Strait and its islands as an area of priceless significance for all time. Bass Strait has the capacity to become one of the world's notable 'protected' areas, and it is quite within our powers today to ensure its survival for future Australians as a place of unlimited personal and intellectual renewal.

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A BIBLIOGRAPHY OF BASS STRAIT 1797-1971

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INTRODUCTION

Although Tasman discovered and named Van Diemen's Land in 1642, it was not until 1798 and 1799 that Bass and Flinders demonstrated to Europeans the existence of what was to become known as Bass Strait. The region became important immediately both for navigational and for political reasons. Settlements were attempted at several sites near the Strait and a sealing industry developed, based almost entirely on the islands and islets of the Strait. This industry, Australia's first export earner, left a residual population on the islands which in the course of the nineteenth century developed a way of life of its own which persists, in an attenuated form, to our own day.

The deportation of Tasmanian Aborigines to the islands and their subsequent establishment on Flinders Island involved colonial administration. Development of intracolony and overseas trade necessitated the building of lighthouses, which created points of official occupation and authority within the scattered islands. Later in the nineteenth century came the first serious attempts to promote land settlement on Flinders and King Islands, and this, extended with government aid after the two world wars, supplemented the population and led to the development of a basically agricultural community. Today Bass Strait is the subject of unprecedented interest, partly because of recent oil and gas discoveries, partly because there has been an increasing realisation of its undoubted scientific potential. Perhaps also a growing sentiment for personal adventure and discovery has added to its appeal.

Bass Strait has an extensive literature, one which started soon after European settlement. In this Bibliography, we have attempted to provide a comprehensive list of references dealing with both scientific and non-scientific aspects of Bass Strait, particularly since the rich historical material has much to offer the scientist. For our purposes, we

have defined Bass Strait to include the water and islands from the west of King Island (approximately 143° 50'E) to the east of the Furneaux Group (approximately 148° 30'E). Thus we have generally excluded material dealing with the Victorian and Tasmanian coastlines, the main exception here being material relating to lighthouses. We have also excluded Lawrence Rocks and Lady Julia Percy Island, the islands of Westernport Bay, those islands in Corner Inlet and the West Gippsland islands off Port Welshpool and Port Albert.

In selecting the included material, and in setting it out we have attempted to make the Bibliography of maximum value to the user. Citations have followed uniform scientific forms where appropriate: elsewhere we have quoted material in full where we felt ambiguity or confusion was likely. Though this Bibliography is basically concerned with published material, we have included selected references to manuscripts, theses and newspaper items which we have considered important. We have not listed those works which give little more than peripheral mention to Bass Strait; generally, neither have we included material which contains a duplication of primary sources.

In the Bibliography an item is listed in full only once, in Section I under the subject group heading to which we feel it is most appropriate. Within each subject heading the references are listed alphabetically, but they are numbered consecutively throughout the entire list. Any reference which is especially relevant to other subjects is also listed under these headings by number only. In Section II cross-references are given, again by number only, to the islands of Bass Strait. Here we have tried to be as consistent as possible, but where a reference mentions many islands we have cross-referenced only to the most important. Some general works, such as the *Sailing Directions Victoria including Bass Strait* which

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mentions virtually every rock in Bass Strait, have not been cross-referenced at all, although they contain useful information on all islands. In addition, users should note that rich though the sources mentioned in our sections on 'Lighthouses' and 'Missionary Voyages' are in references to individual islands and topics, no attempt has been made to cross-reference them. It is assumed that those seeking further information on, say, Cape Barren Island will realise that the section on 'Missionary Voyages' has much to offer them. Finally, in Section III an author index will be found.

Some examples may clarify our approach. Thus an article on the 'Gannets of Cat Island' is given in full under 'Birds-Gannet'. The appropriate number for this article will be found under 'Cat Island' in Section II and the author will be credited with the reference number in Section III. An article such as the Tasmania Parliamentary report of 1908 by J. E. C. Lord, which deals with the problems of the Cape Barren Islanders, is quoted in full under 'Aborigines—Cape Barren Islanders'. This article makes extensive reference to the mutton-birds of Bass Strait, and is accordingly listed by number under the heading 'Birds—Mutton-birds'. The paper is geographically cross-referenced by number to the Furneaux Group as well as to several islands which it mentions, and is attributed to both Tasmania, Parliament and J. E. C. Lord in the author index.

CONTENTS

The references in this Bibliography have been separated into the following groups:

Aborigines: Cape Barren Islanders.
Aboriginal Establishment, Flinders Island.
Tasmanian Aborigines.

Agricultural and Economic Development.

Biogeography.

Birds: General.
Cape Barren Geese.
Gannets.
Mutton-birds.

Botany.

Climate.

Conservation.

Discovery and Exploration.

Fiction.

Fish and Fisheries.

We have generally followed the 'Atlas of Tasmania' (Ref. No. 805) for usage and spelling of the island names, so, for example, references to Guncarriage Island are listed under its official, but less pleasing name of Vansittart Island. Where references have mentioned Hummock or Hummocky Island in a context which indicates that Prime Seal Island is meant, they are listed under the latter name to avoid confusion with Three Hummock Island in the Hunter Group. Swan Island here means the island of that name off Cape Portland, northeastern Tasmania, not the one in Port Phillip Bay.

Although we have restricted material included below to that published in 1971, or earlier, we are aware that errors of omission have occurred. In the development of any working bibliography the problems of inclusion, and of taxonomy, present difficulties and we would hope for criticism and suggestions for the improvement of any subsequent revision we may make.

ACKNOWLEDGMENTS

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Geology: General.
Geomorphology.
Oil and Gas.
Palaeontology.
Scheelite.
Tin.

History and Description.

Hydrography and Hydrology.

Intertidal Ecology.

Invertebrates.

Lighthouses.

Mammals.

Missionary Voyages.

Natural History.

Reptiles and Amphibians.

Sealing and Whaling.

Ships and Shipping.

Addenda.

SECTION I

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MUTTON-BIRDS

There is a vast literature relating to the Mutton-bird or Short-tailed Shearwater, *Puffinus tenuirostris*, but we have included here only those references that are particularly relevant to the Bass Strait region. More extensive lists can be found in the various papers by D.L. Serventy.

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609. 1856. Australian lighthouses. *Parl. Pap., Victoria* 1856-7, Vol. 4.
610. 1856-7. Lighthouses at Cape Schanck and Wilson's Promontory. *Parl. Pap., Victoria* 1856-7, Vol. 4.
611. 1856-7. Lighthouses....*Parl. Pap., Victoria.*

SEE ALSO: 89, 383, 550, 551, 554, 712.

LIGHTHOUSES

The establishment of lighthouses in Bass Strait was one of the earliest forms of inter-colonial collaboration. The relevant Parliamentary papers, and the minutes of evidence attached to them, give a wealth of detail on navigation in the Straits. So far as is known, this is a complete list of the relevant papers, arranged chronologically.

598. 1841. Light houses in Bass' Strait. Report from the committee on light houses....*Parl. Pap., Legislative Council, N.S.W.*
599. 1842. Light houses in Bass' Strait. Report from the committee on light houses....*Parl. Pap., Legislative Council, N.S.W.*
600. 1845. Light houses. Report from the select committee....*Parl. Pap., Legislative Council, N.S.W.*
601. 1845. Light houses, Bass's Straits. [Message from His Excellency the Governor], *Parl. Pap., Legislative Council, N.S.W.*
602. 1846. Light houses in Banks' Straits. *Parl. Pap., Legislative Council, N.S.W.*
603. 1849. Light houses in Bass's Straits. Report from the select committee. *Parl. Pap., Legislative Council, N.S.W.*
604. 1853. Lighthouses. Correspondence respecting the lighting of the coast of this colony. *Parl. Pap., Legislative Council, Victoria* Vol. 1.
605. 1853. Lighthouses. Correspondence relative to the lighthouse on Kent's Group. *Parl. Pap., Legislative Council, Victoria* 1853-4, Vol. 1.
606. 1853. Report from the select committee of the Legislative Council on lighthouses.... *Parl. Pap., Legislative Council, Victoria* Vol. 1.
607. 1855. Lighthouse on King's Island. *Parl. Pap., Legislative Council, Victoria* 1855-6, Vol. 1.
612. 1863. King's Island Light-houses. *Parl. Pap., House of Assembly, Tasmania* Vol. 9.
613. 1865. Tasmanian highway lights in Banks' and Bass's Straits. *Parl. Pap., House of Assembly, Tasmania* Vol. 12. No. 18.
614. 1865. Tasmanian highway lights in Banks' and Bass's Straits. *Parl. Pap., House of Assembly, Tasmania* Vol. 12. No. 36.
615. 1865. Highway and ocean lights....*Parl. Pap., House of Assembly, Tasmania* Vol. 12. No. 48.
616. 1873. Marine departments in Australian colonies....*Parl. Pap., Victoria* Vol. 3.
617. 1875. King Island....*Parl. Pap., Victoria* 1875-6, Vol. 2.
618. 1880. Currie Harbour light....*Parl. Pap., House of Assembly, Tasmania* Vol. 39. No. 43.
619. 1880. Ocean lighthouse service....*Parl. Pap., House of Assembly, Tasmania* Vol. 39. No. 56.
620. BENNETT, I., 1955. South to Maatsuyker: A visit to lonely lighthouses in Bass Strait and Tasmanian waters. *Walkabout* May.
621. MURRAY-SMITH, S., 1969. Bass Strait: lighthouses and wrecks. In *Bass Strait Australia's last frontier*. pp. 89-96. Sydney: Australian Broadcasting Commission.
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MAMMALS

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626. COURTNEY, J., 1963. King Island, Bass Strait - the remarkable faunal unit (with description of a new form of Potorous rat-kangaroo). *Aust. Avicult.* 17:18-20. [In *Aust. Avicult.* 17:92, two letters from the author are published, one nominating a type specimen.]
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644. MORRISON, C., 1941. Notes and specimens. *Wild Life, Melb.* 3:213. [*Pteropus poliocephalus* on King Island.]
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650. SCOTT, H.H., 1906. Memoir on *Procoptodon rapha* (Owen) from King Island. *Queen Vict. Mus. Launceston Brochure*. [Unnumbered, but in fact the second brochure.]
651. SCOTT, H.H., 1912. Memoir on *Nototherium tasmanicum* (Owen). *Queen Vict. Mus. Launceston Brochure* 4.
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653. SCOTT, H.H., 1917. Some palaeontological notes. *Queen Vict. Mus. Launceston Brochure* 6.
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660. SHARLAND, M., 1962. *Tasmanian wild life*. Melbourne: Melbourne University Press. [Chapter 4: Flinders Island wombat.]
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663. WARNEKE, R.M., 1966. Seals of Westernport. *Victoria's Resources* 8:2-4.
664. WARNEKE, R.M., (n.d. = 1968). The fur seal. In *Wildlife in south-eastern Australia*. Ed. J.K. Dempster. pp. 16-22. Sydney: Australian Broadcasting Commission.
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- SEE ALSO: 87, 116, 118, 125, 153, 214, 215, 383, 712, 732, 740, 741, 743, 810.

MISSIONARY VOYAGES

In the second half of the nineteenth century a number of Tasmanian divines took pains to visit the scattered populations of the islands of Bass Strait on what were known as 'missionary voyages'. It is on the accounts of these voyages that much of our social knowledge of the people of Bass Strait in this period, and their environments, is based. So far as is known, the following is a complete listing of the reports of these undertakings.

GENERAL

666. [DAVIES, R.R.], 1852. Tasmanian missions. *Tasmanian Church Chronicle*. 1:2 (6 March).

BISHOP BROMBY

667. BROMBY, C.H., 1876. The bishop's visit to the Furneaux Islands. *Church News* (Hobart) 6(27):424-425 (March). [See also: *Launceston Examiner*. 8 February, 1876.]

CANON BROWNRIGG

668. BROWNRIGG, Rev. Canon [M.B.], 1872. *The cruise of the 'Freak': A narrative of a visit to the islands in Bass and Banks Straits with some account of the islands*. Launceston.
669. BROWNRIGG, M.B., 1873. A narrative of a visit to the islands in Bass's and Banks's Straits in the cutter 'Dolphin'. *Launceston Examiner* 18 March.
670. BROWNRIGG, M.B., 1874. A narrative of a mission visit to the Kent and Furneaux Groups. *Launceston Examiner* 24 February.
671. BROWNRIGG, M.B., 1875. The mission visit to the islands in Banks and Bass Straits in the cutter 'Kate'. *Launceston Examiner* 4 May.
672. BROWNRIGG, M.B., 1876. Narrative of the fifth mission visit to the islands in Banks and Bass Straits. *Launceston Examiner* 12 February.
673. BROWNRIGG, M.B. 1877. Narrative of the sixth mission visit to the islands in Banks and Bass Straits. *Launceston Examiner* 6 February.
674. BROWNRIGG, M.B., 1878. Narrative of the seventh mission visit to the islands in Banks and Bass Straits. *Launceston Examiner* 4, 6 February.
675. BROWNRIGG, M.B., 1879. Narrative of the eighth mission visit to the islands in Banks and Bass Straits. *Launceston Examiner* 28 February [This, and subsequent *Launceston Examiner* reports of successive missions, were reprinted in pamphlet form.]
676. BROWNRIGG, M.B., 1879. Canon Brownrigg's eighth visit to the islands in Banks' and Bass' Straits. *Church News* (Hobart) 7(32):501 (August),
677. BROWNRIGG, M.B., 1881. Narrative of the ninth mission visit to the islands in Banks and Bass Straits. *Launceston Examiner* 9 February.
678. BROWNRIGG, M.B., 1882. Narrative of the tenth mission to the islands in Banks and Bass Straits. *Launceston Examiner* 11, 15 March.

679. BROWNRIGG, M.B., 1882. Narrative of the tenth mission to the islands in Banks and Bass Straits. *Church News* (Hobart) n.s. 1(4):51-53 (April); 1(5):70-71 (May).
680. BROWNRIGG, M.B., 1883. Narrative of the eleventh mission visit to the islands in Banks and Bass Straits. *Launceston Examiner* 3 March.
681. BROWNRIGG, M.B., 1883. Narrative of the eleventh mission visit to the islands in Banks and Bass Straits. *Church News* (Hobart) 2(16):59-60 (April); 2(17):70-71 (May).
682. BROWNRIGG, M.B., 1884. Narrative of the twelfth mission visit to the islands in Banks and Bass Straits. *Launceston Examiner* 8, 10 March.
683. BROWNRIGG, M.B., 1884. Narrative of the twelfth mission to the islands in Bass and Banks Straits. *Church News* (Hobart) 3(26):252-253 (April).
684. BROWNRIGG, M.B., 1885. Narrative of the thirteenth mission visit to the islands in Banks and Bass Straits. *Launceston Examiner* 7 March.
- REV. J. FEREDAY
685. FEREDAY, J., 1871. Furneaux mission. *Church News* (Hobart) 4(4):58-60 (April).
- BISHOP MONTGOMERY
686. HART, P.R., 1963. The Church of England in Tasmania under Bishop Montgomery, 1889-1901. M.A. Thesis, University of Tasmania. [Chapter 3 gives a general account of Montgomery's relations with the islanders.]
687. MONTGOMERY, H.H., 1891. The Furneaux Islands. *Church News* (Hobart) 10(4):444-445 (April); 10(5):452-453 (May); 10(6):466 (June); 10(7):492-493 (July); 10(8):498-499 (August); 10(9):515-517 (September); 10(10):530-531 (October); 10(12):562-563 (December).
688. MONTGOMERY, H.H., 1892. My second visitation of the Furneaux Islands. *Church News* (Hobart) 11(3):614-615 (March); 11(4):630-631 (April); 11(6):681-682 (June).
689. MONTGOMERY, H.H., 1893. Visit to the Bass' Straits Islands, 1893. *Church News* (Hobart) 12(3):818-819 (March); 12(4):834-835 (April); 12(6):870-871 (June).
690. MONTGOMERY, H.H., 1894. Visitation of the Furneaux Islands, June 1894. *Church News* (Hobart) 13(8):123-125 (August).
691. MONTGOMERY, H.H., 1895. A visitation of King Island and of the lighthouses. *Church News* (Hobart) 14(6):284-285 (June).
692. MONTGOMERY, H.H., 1895. Visitation of the Furneaux Islands. *Church News* (Hobart) 14(10):351 (October).
693. MONTGOMERY, H.H., 1896. Visitation of the Furneaux Islands. *Church News* (Hobart) 15(4):446-447 (April).
694. MONTGOMERY, H.H., 1898. King Island. *Church News* (Hobart) 17(9):911-912 (September).
695. MONTGOMERY, H.H., 1898. Visitation of the Furneaux Islands. *Church News* (Hobart) 17(10):927-928 (October).
696. MONTGOMERY, H.H., 1899. Visitation of the Furneaux Islands. *Church News* (Hobart) 18(10):1123-1125 (October).
697. MONTGOMERY, H.H., 1901. My last visitation of the Furneaux Islands. *Church News* (Hobart) 20(9):142-143 (September).
- BISHOP NIXON
698. NIXON, F.R., 1857. *The cruise of the 'Beacon': A narrative of a visit to the islands in Bass's Straits...* London: Bell & Daldy.
699. NIXON, F.R. 1864. Tasmanian missions and cathedral. *Church News* (Hobart) 1(31):389 (21 November).
- ARCHDEACON REIBEY
700. REIBEY, Archdeacon, 1866. Cruise of the 'Gift'. *Church News* (Hobart) 2(17):261 (4 May).
701. TASMANIA. PARLIAMENT, 1862. Letter from the Venerable Archdeacon Reibey, on the subject of the half-caste islanders in the straits. *Parl. Pap. Legislative Council* No. 17. [Repeated as House of Assembly Pap. No. 22.]
702. TASMANIA. PARLIAMENT, 1863. Half-caste islanders in Bass's Straits. Report of the Ven. Archdeacon Reibey. *Parl. Pap. Legislative Council* No. 48.
- BISHOP SANDFORD
703. STEPHENSON, B.C., 1885. The Bishop's visit to the islands. *Church News* (Hobart) 4(38):456-457 (April).
- NATURAL HISTORY
704. ANON., 1888. Field naturalists on King Island. *Australasian* 17 March.
705. ANON., 1890. The Field Naturalists' expedition to Kent Group. *Argus* 29 November.

706. ANON., 1891. Our visit to Kent Group. *Australasian* 3 January.
707. ANON., 1893-1894. Scientific exploration of Bass Straits islands. *Argus* 23 December 1893; 2 January 1894. [Account of naturalists' excursion.]
708. ANON., 1901. King Island. *Victorian Nat.* 18:68.
709. ANON., 1947. Rodondo adventure - primordial scrubs surveyed. *Wild Life, Melb.* 9:86-89.
710. ASHWORTH, H.P.C. and (W.H.) D. LE SOUEF, 1895 Albatross island and the Hunter Group. *Victorian Nat.* 11:134-144.
711. ATKINS, W.N., 1909. Notes on a trip to the Straits islands. *Tasm. Nat.* 2:10-12.
712. ATKINSON, E.D., 1890. Notes of a short trip to the islands of western Bass Straits. *Victorian Nat.* 6:156-164.
713. BARRETT, C.L., 1909. A naturalist in Bass Strait. *Victorian Nat.* 26:51-55.
714. BARRETT, C.(L.), 1919. *In Australian wilds: The gleanings of a naturalist.* Melbourne: Melbourne Publishing Company.
715. BARRETT, C.(L.), 1939. *Koonwarra: A naturalist's adventures in Australia.* London: Oxford University Press.
716. BARRETT, C.(L.), 1944. *Isle of mountains.* Melbourne: Cassell.
717. BARRETT, J.W., 1918. *The twin ideals. An educated Commonwealth.* 2 Vols. London: Lewis and Co. [Vol. 2, chs. 77-81, reprint articles from *Argus* on the natural history of the islands.]
718. BECHERVAISE, J.M., 1947. The Rodondo episode. *Victorian Nat.* 64:18-24. [See also pp. 1-2.]
719. BECHERVAISE, J.M., 1947. Plant and animal life on Rodondo Island. *Wildlife in Australia* April:129-132.
720. BISSILL, W.K., 1888. King Island. *Victorian Nat.* 5:86-87.
721. CAMPBELL, A.J., 1888. Field Naturalists' Club of Victoria expedition to King Island, November 1887. *Victorian Nat.* 4:129-164. [Photographs taken by the 1887 expedition are held in the F.N.C.V. library at the National Herbarium, Melbourne.]
722. CHISHOLM, A.H., 1971. Naturalists in Bass Strait. *Victorian Nat.* 88:43-44.
723. DARRAGH, K. [= T.A. DARRAGH], 1969. (Flinders Island). *Victorian Nat.* 86:321-323. [Report of a talk given to the F.N.C.V. general meeting 13 October 1969.]
724. "FIELD NATURALIST"., 1893. On the Furneaux Group. *Australasian* 30 December.
725. GABRIEL, J., 1894. Report of expedition to Furneaux Group. *Victorian Nat.* 10:167-184. [Photographs taken by the 1893 expedition are held in the F.N.C.V. library at the National Herbarium, Melbourne.]
726. GABRIEL, J., 1896. Further notes from Albatross Island - narrative of a second trip. *Victorian Nat.* 13:3-11.
727. GARREAU, C., 1958. Holiday excursion in the Kent Group. *Victorian Nat.* 75:128-130.
728. GOULD, C., 1872. The islands in Bass' Straits. *Pap. Proc. R. Soc. Tasm.* (1871): 57-67.
729. HILL, R., 1970. *The corner: A naturalist's journeys in south-eastern Australia.* Melbourne: Lansdowne Press.
730. HOPE, J.(H.), 1969. Wildlife of Bass Strait. In *Bass Strait Australia's last frontier.* pp. 73-80. Sydney: Australian Broadcasting Commission.
731. JONES, J., M.A. MARGINSON and S. MURRAY-SMITH, 1970. Southwest Island and other investigations in the Kent Group. *Victorian Nat.* 87:344-371. [Includes section on the birds of the Kent Group by J. Jones; and some detailed weather observations.]
732. LE SOUEF, (W.H.)D., 1891. Expedition of Field Naturalists' Club to Kent Group, Bass Strait. *Victorian Nat.* 7:121-131. [Photographs taken by the 1890 expedition are held in the F.N.C.V. library at the National Herbarium, Melbourne.]
733. LE SOUEF, (W.H.)D., 1902. A visit to the Furneaux Group of Islands. *Victorian Nat.* 18:181-188.
734. LE SOUEF, (W.H.)D., 1902. The Furneaux Group of islands. *Australasian* 1 March.
735. LE SOUEF, W.H.D., (n.d.). *Wild life in Australia.* Christchurch: Whitcombe and Tombs. [Detailed and interesting description of visits to Hunter Group in 1894 and to Furneaux Group in 1904.]
736. LITTLER, F.M., 1910. A trip to Ninth Island. *Emu* 9:141-148.
737. LOTT, C., 1945. Lovely Trefoil Island. *Walkabout* November.
738. McCANCE, N., 1961. Wild life on King Island. *Aust. Avicult.* 15:89-90.

739. MARGINSON, M.A. and S. MURRAY-SMITH, 1969. Further investigations in the Kent Group. *Victorian Nat.* 86:254-268.
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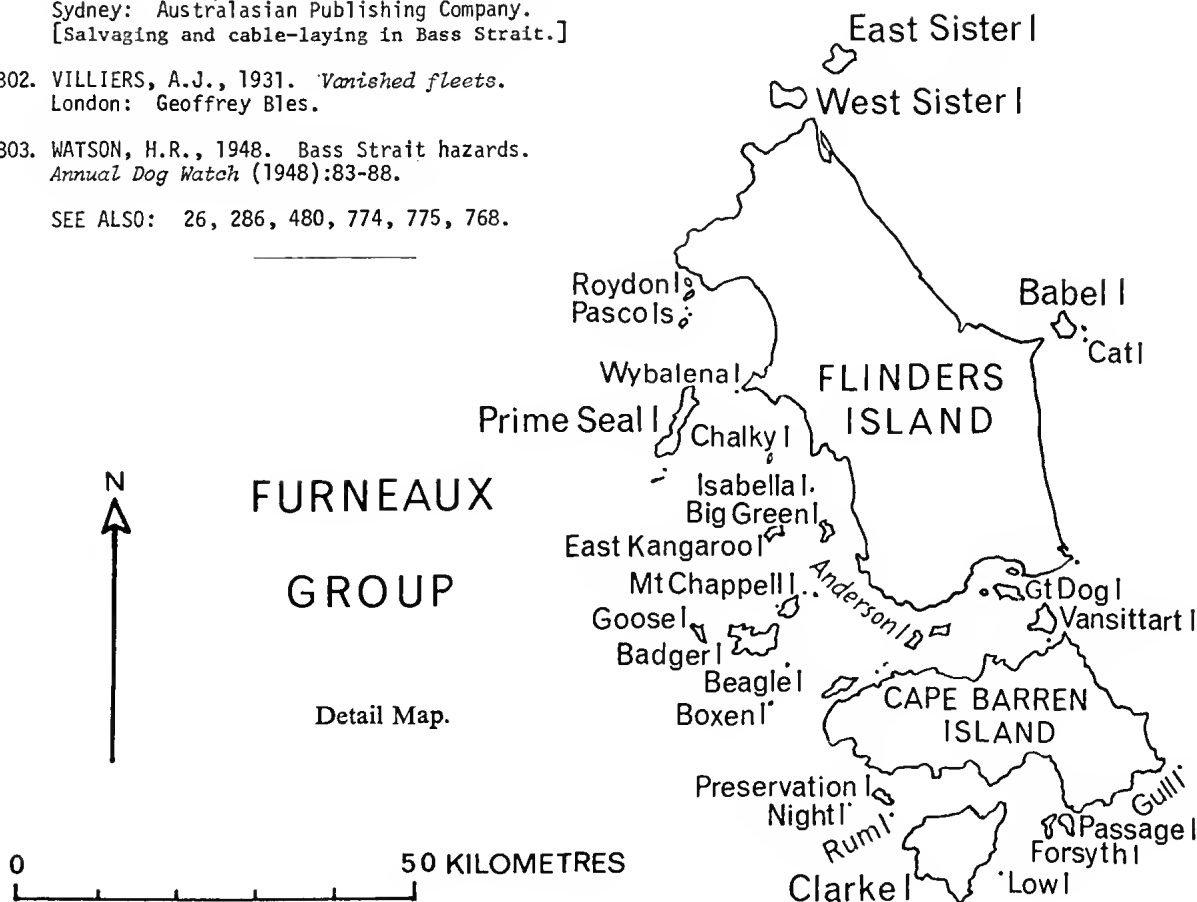
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APPLICATION OF RECENT HYPOTHESES TO CHANGES OF SEALEVEL IN BASS STRAIT, AUSTRALIA

By EDMUND D. GILL*

ABSTRACT: The shores of Bass Strait are (1) stormy, (2) microtidal, and (3) of Mediterranean climate. Hypotheses related respectively to each of these fundamental factors are examined.

1. *Storminess.* Emerged high energy deposits such as boulder beds have been explained by a period of greater storminess with the sea at its present level. Wilson and Hendy (1972) show that great storminess is associated with lower sealvels when the thermal gradient between poles and equator was greater. A higher sealvel is therefore a more acceptable interpretation for the emerged boulder beds of Bass Strait, especially when they overlie an ancient platform too high to be cut by present sealvel and covered by weathered colluvium.

2. *Small Tidal Range.* West Bass Strait has a tidal range ~ 1 m, which increases to the east. Davies (1964) has shown the significance on a world scale of tidal range. In west Bass Strait the small tidal range concentrates marine attack, strongly eroding any soft bed within its limits. High tides from meteorologic effects may reach $\times 2.6$ normal range, thus developing the supratidal zone. Biologic and physical zones are compressed, while tidal currents are negligible, and salt marsh development depressed.

3. *Climate.* Authors have placed the power of the sea (physical) and water layer weathering (chemical) in apposition, regarding the latter as universally operative as the former. Gill (1972) considers the latter to be a function of the tropics, and the pools on platforms in Bass Strait to be of quite a different character.

INTRODUCTION

Bass Strait is stormy, microtidal, and Mediterranean in climate. These three fundamental characteristics strongly influence the nature of the shores, and so the record of the changes of sealvel. To understand present processes is to improve ability to read the evidence of past sealvels. Recently, new hypotheses have been advanced relevant to each of the above three characteristics of Bass Strait. It is of value to examine how these hypotheses affect the interpretation of its coasts. Moreover, this procedure produces new programmes for the study of sealvel shifts.

STORMINESS IN BASS STRAIT

Bass Strait is the waterway between Victoria and Tasmania. Both these States have lakes near enough to the sea to suffer comparable subaerial weathering, yet the marine shores and the lake shores possess quite different morphologies. The chief reason is the different energy status, the former being high and the latter low. The shores

of Bass Strait are highly energetic; they yield (for example) supratidal platforms and boulder beds not seen on lake shores. On the sea coast, the change in morphology from exposed headland to quiet inlet is largely a function of decreasing dynamics.

Boulder beds now above the reach of the stormiest seas are found on the north coast of Tasmania (Chick 1970, Davies 1961, 1965, Jones 1965), King Island (Jennings 1959), and the south coast of Victoria (Gill 1972a,b). Boulder beds exist above the reach of the stormiest seas, i.e. the most energetic waves no longer hit these boulders, much less move them. Indeed, they are often covered with colluvium and/or soil plus vegetation, and the higher ones overlie weathered platforms. Occasional big storms may throw up boulders, but they cannot cut a platform. Boulder beds in three situations have been noted on the Otway coast of Victoria:

1. *Arkose boulders with shells* on an extension of the present siltstone and arkose intertidal

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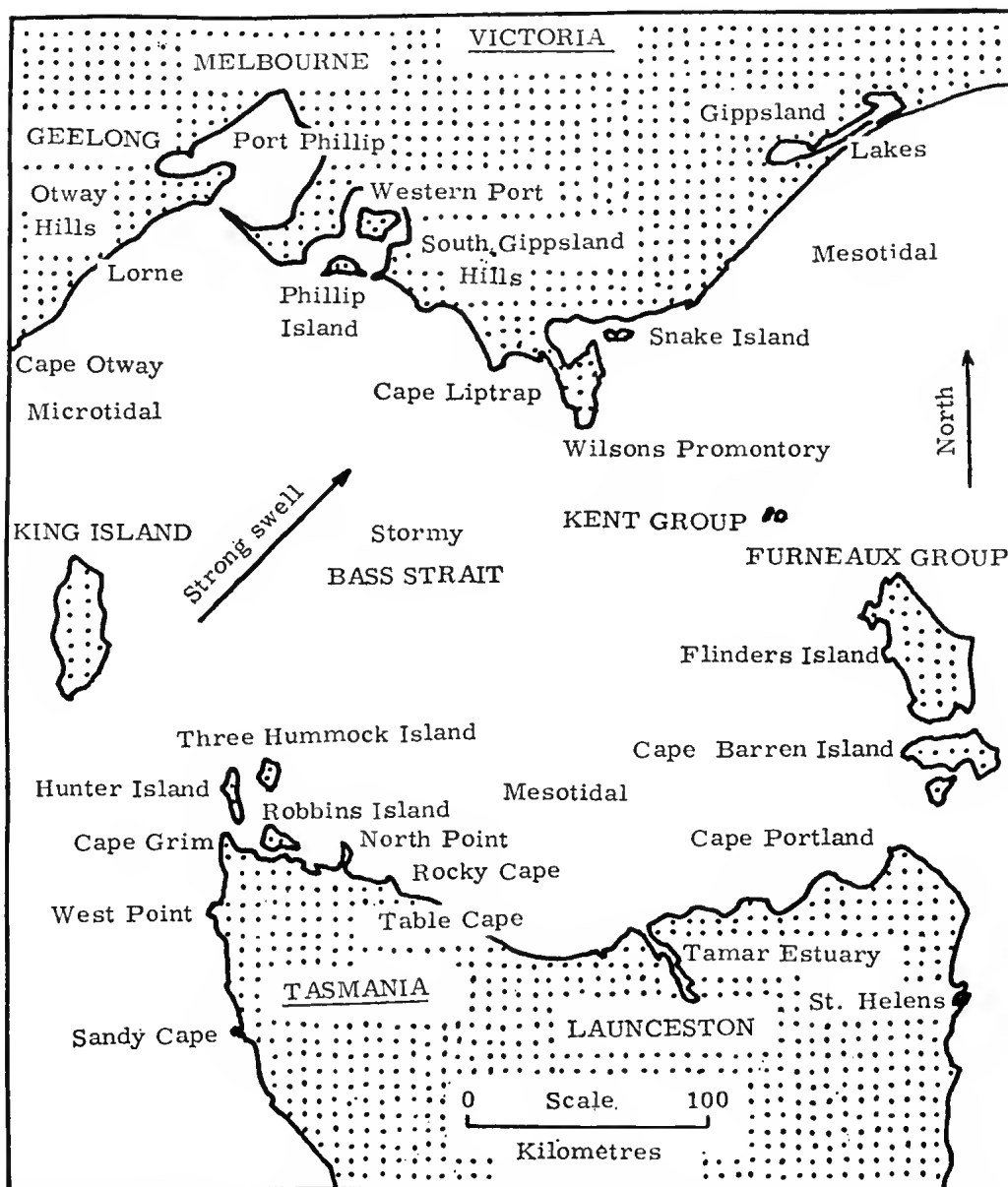


FIG. 1—Map of Bass Strait with indications of microtidal and mesotidal areas, plus direction of swell.

platforms, covered with sand plus vegetation. Considerable energy would be necessary at the site to emplace these boulders, but the present sea does not even wash away the sand and soil. This has been the condition for a long while, because a soil has formed on the sand. For surveyed sections see Gill 1972, Figs. 2-3. At Browns Creek, marine shells occur among the boulders of such a bed, while SW. of Boggaley Creek, beach rock formed by groundwater was found over and among such

boulders. Radiocarbon assays are being made of the organic materials.

2. *Boulders with shells* forming a ramp behind a supratidal platform, commonly as the continuation of a channel or such structure (Gill 1972 b, Figs. 10-11). The boulders now have soil between them and often over them plus vegetation (sometimes trees). These deposits could be the supratidal environment equivalent of (1) above.

3. *Boulders without shells* on an emerged plat-

form, both weathered, standing ~ 7.5 m (surveyed at Cumberland River) above present low sealevel (tidal range ~ 1 m) and commonly covered by a thick colluvium (up to 20 m) of red soil and unsorted angular rocks capped by a gray soil. In north Tasmania, boulder beds occur covered by forest.

The interpretation of boulder beds has always been a matter of considerable uncertainty, the chief misgiving being that such may be the record of a more stormy period with sealevel as at present, and not evidence of a sealevel change. Thus usually the very high boulder beds have been accepted as evidence of shift of sealevel, but not the lower ones. For example, Jones (1965) described a seaward-facing cave near Wynyard in which a cemented water-rolled conglomerate adheres to parts of the ceiling. From this he deduced a former sealevel of the order of 30 m above the present. On the other hand, the boulder beds I list above have been explained as a function of storms.

On this question, the hypothesis of Wilson and Hendy (1972) has a direct bearing. Storminess is described as a function of the difference in mean temperature between the equator and the poles. This difference can be traced in the past by oxygen isotope analyses. The assay of deep polar cores provides the information previously missing to check such an idea. On this hypothesis, the periods of great storminess existed when the poles were coldest and sealevels lowest; the periods of least storminess existed when the poles were warmer than now and sealevels higher. It is therefore unlikely that the emerged boulder beds are due to a period of great storminess with the sea at its present level. Conversely, it is likely that they were due to a higher sealevel bringing the dynamics of the waves into play higher on the coastline. These considerations apply also to other high energy emerged coastal deposits such as storm beaches, terraces of coarse shell grit, and platforms in exposed positions now covered with soil plus vegetation.

Beneath the sea on the continental shelf many deposits of coarse sediments that apparently belong to former lower shorelines have been found. When these have been studied further, they should throw light on the question of to what extent higher dynamics are associated with the lower sealevels. In Australia during the Last Glacial, there were more widely spread active dune systems than at present.

Approaching the subject of the Bass Strait boulder beds from another angle, it may be anticipated that, if they are a record of higher sealevels, correlative stillwater marine facies at

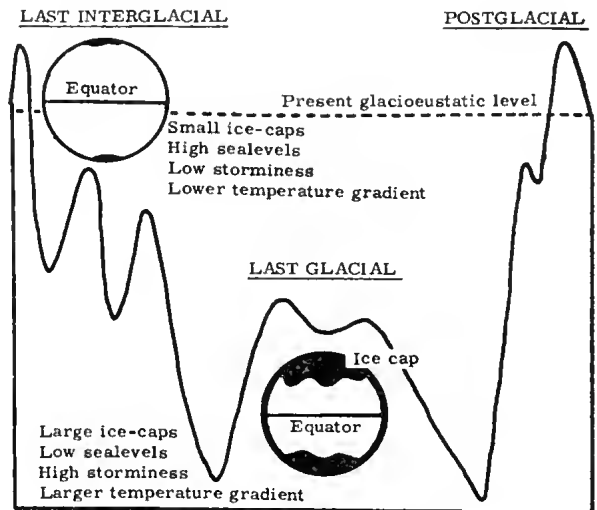


FIG. 2—Generalized graph (after Emiliani) of temperature changes, and therefore also of glacioeustatic sealevel changes, since the Last Interglacial. Gross changes in polar-equatorial temperature gradients with time, and their results, are indicated.

this level should be present, when due allowance has been made for the fact that they erode more easily than boulder beds. By reason of the rapid rate of retrogradation on aeolianite coasts, for example (~ 4 cm/yr in west Victoria), it is unlikely that the open ocean facies of previous higher sealevels will remain. However, on coasts of resistant rocks, such as fresh basalt, it should be possible to locate both the open ocean and the stillwater facies because of the slow rate of wear. Indeed this has been done on the Woodbine Basalt (Gill 1973) between Port Fairy and Cape Reamur, west Victoria. On the open coast emerged channels, emerged potholes, shell grit terraces out of reach of the sea, and such have been found. Postglacial dates of various ages have been obtained. *Katelysia* shells from a stillwater facies behind a basalt barrier, at the South Beach caravan park, Port Fairy, were dated 3880 ± 90 y BP (GaK-3918). On the open ocean coast, an emerged channel with well-rounded boulders (up to 1 m diameter but usually less) and shell grit was dated 2840 ± 80 y BP (GaK-3917) on whole to partly broken shells. These dates correlate with some obtained elsewhere, but more work needs to be done to match contemporaneous high and low energy facies of various ages at a number of points along the coast. The main difficulty is that this requires resources for numerous excavations and numerous radiocarbon assays.

MICROTIDAL SHORES

With the emergence of the science of ecology, some attention has been given to this aspect of coastal studies. Davies (1964) provided a fresh approach by pointing out the relevance to the coasts of the world of tidal range and swell régime. Bass Strait is microtidal in the west half, and grades into mesotidal in the east. Because the Southern Hemisphere is the ocean hemisphere, the storm belt is very much better defined than in the Northern Hemisphere. One result is a strong swell régime. Southwest swell dominates the seas of the south side of Australia, and it has been 'invoked to explain beach alignment in southern Australia generally' (Davies 1960).

Taking up Davies' point about the importance of tidal range, the writer has noted the following distinctive features of the microtidal rocky coasts of Bass Strait:

1. *Concentration of Marine Attack.* The surf zone is one of Nature's power tools. In that zone the main erosive work of the shoreline is done. On a macrotidal coast of say 10 m, the surf zone passes across the (usually) wide rock platform as the tide comes in. However, on a microtidal coast of say 1 m, there is less transgression, and so the amount of erosion at a given site is much greater. Expressed another way, it can be said that, at a given site on a macrotidal coast of 10 m tidal range, the number of broken wave and swash strikes will be x , while on a microtidal coast of 1 m tidal range it will be $10x$. Thus a concentration of sea energy occurs on the microtidal coast, which results in a more rapid landward move of the shoreline profile. The average number of times that a heavy boulder in a pothole or channel is agitated by high energy waters per tidal change is much greater on a microtidal than on a macrotidal coast. Therefore, the amount of corrasion is much greater. The average number of high energy water impacts on a joint block on a microtidal coast is far greater than on a macrotidal coast, and so the amount of quarrying (Gill 1972) and plucking (Gill 1971) is much greater per unit area.

Similarly, the number of times armed surf (i.e. laden with rocks, sand and shells) sweeps over a given square metre of shore rock is much higher on a microtidal than on a macrotidal coast. Therefore, the amount of abrasion is much greater thereon. In the extreme case where the tidal range is of the order of only (say) 30 cm, the marine attack is virtually on the same level at the time and so very concentrated. Retrogradation is then faster. As Davies (1964, p. 137) says, 'The importance of variation in water level is obvious

enough, for this determines the degree to which wave attack is concentrated on a particular plane.'

2. *Area for platform species is less.* The number of square metres available for the accommodation of intertidal organisms is much less on a microtidal coast than a macrotidal one (other things being equal), but as far as I have been able to observe the distribution per unit area is not significantly different, so the effects of biologic activity are much the same per unit area on the two types of coast. Thus there is a much smaller biomass of intertidal life on a microtidal coast than on a macrotidal one. Because there is so much more life in the intertidal zone of a macrotidal coast, industries such as the collection of seaweed are to be found on such coasts, e.g. Brittany.

3. *Erosion of Soft Strata Dependent on Critical Placement.* Because the zone of surf attack on a microtidal coast is so narrow, the level at which a layer of soft (and so readily erodable) rock occurs is very critical, as also is its disposition (dip and strike). For instance, a horizontal palaeosol in aeolianite within or near a 1 m tidal range (which we have taken as an example of a microtidal situation) will be rapidly eroded and cause massive cliff falls. Conversely, if it lies in the upper supratidal zone, it is likely to be lithified by the accumulation of secondary carbonate.

Or again, a soft siltstone 0.3 m thick in much harder arkose strata, as on the Otway coast of Victoria, can cause rapid demolition if it occurs within the 1 m tidal range. Opposite Little Stony Creek at Lorne, Victoria, a soft siltstone occurs in the horizontal arkose strata within the narrow tidal range, and is being tunneled by marine erosion, resulting in collapse of the overlying rocks. Pebbles washed round in these tunnels rapidly abrade the walls and widen the channels, admitting more sea and pebbles.

At Boggaley Creek, further SW. on the same coast (NE. of Wye River) the strata strike oblique to the shore and dip at 30° . A siltstone band, brought into the tidal range by the dip of the strata, is being rapidly eroded by the sea, causing collapse of the overlying arkose, which breaks up according to its joint pattern. One result is an exceptionally large number of boulders on the shore platform (SW. side of creek). These are moved by the sea and so increase erosion. Thus the position of a soft stratum is critical on a microtidal coast because the erosion zone is so narrow, and the marine attack so concentrated.

4. *Meteorologic Variation of Tidal Range is Significant.* On a macrotidal coast, the degree to which tides are lower or higher because of weather

conditions is not usually a large percentage of the tidal range. Lower tides are caused by strong off-shore winds, for example, and higher tides by on-shore ones. On a microtidal coast, however, such differences may be a significant percentage of the tidal range or even exceed it. At Hobsons Bay, Melbourne, normal tidal range is 0.76 m, but abnormally high tides due to meteorologic conditions have been recorded up to 1.96 m, which is 2.6 times the norm (Bradley 1949, 1955, 1957).

5. *Dominating Supratidal Zone.* Where a coast is stormy and microtidal, the supratidal zone ranges through a greater elevation than the intertidal zone. On the Otway coast of Victoria, where the hills commonly come down steeply to the sea, the spindrift from storms rises to the order of 100 m as the leaves killed by salt testify. This would be an extreme definition of a supratidal zone. Some would define this zone by the height of splash, but this varies greatly according to the exposure of the site, the morphology of the rocks against which the waves break, and the depth of water offshore. Probably the best definition is the biologic one. Nerite molluscs are characteristic of this zone and they can be used to define it. Because on a stormy microtidal coast the tidal range is narrow and the storm waves rise high, there is a great deal of activity above high water level. Because the plane of marine attack does not alter much, there is a concentration of energy in the supratidal zone during storms, with the result that abrasion occurs that would not take place on a macrotidal coast. Therefore *supratidal shore platforms are more readily developed in such an environment than elsewhere.* More erosion of the cliffs takes place, and more rock falls occur. Thus, while rocks are absent or rare on some platforms, they are common on the platforms of stormy microtidal coasts. These boulders provide the tools for further erosion.

6. *Tidal Currents Negligible.* On macrotidal coasts the large tidal range results in powerful tidal currents which deeply scour the subtidal zone. On a microtidal coast the movements of water are comparatively small and smooth, so that tidal currents are negligible, and this is not one of the significant erosive energies of that environment.

7. *Biologic Zonation Compressed.* Because of the narrow tidal range on a microtidal coast, the biologic zones of the intertidal belt are compressed, so that they also are very narrow. To illustrate again from western Victoria, five biologic zones can be distinguished in the small tidal range of 1 m.

8. *Physical Zonation Compressed.* On the ex-

posed microtidal basalt coasts between Port Fairy and Cape Reamur in west Victoria, one can distinguish a series of erosional zones along the shoreline. There are pavements where the main force of the ocean's energy is effective to quarry blocks of basalt along joint planes and throw them further back on the shore profile. There is a zone where the boulders are not swept away, but the energy is high enough to agitate them to excavate pools and potholes. Then there is the zone of general boulder accumulation. Above that is a zone characterised by subaerial weathering. As the plane of marine attack is much narrower on a microtidal coast, these physical zones are naturally much more compressed than on a macrotidal coast.

9. *Salt Marsh Development.* Broad salt marsh development characterises the macrotidal coast, but is very depressed on a microtidal coast because of the small tidal range. On the latter, salt marsh development is minor. Salt marshes on a small scale are found beside tidal creeks, and in such sites.

The features of a microtidal coast listed above are sufficient to prove that the narrow tidal range has many implications, resulting in a characteristic type of shoreline organization. Narrow tidal range places its own impress on a coast. In coastal descriptions, therefore, it is important that the tidal range be given, and any special characteristics that accompany it. In west Bass Strait the coast is microtidal, and on many days only one high and one low tide occur, instead of the usual two highs and two lows. This is the tidal type C of King (1959). This characteristic even further reduces the limited tidal energy of the coast and so the tidal currents can be neglected as a source of erosive energy. On the other hand, there is a fetch all the way from Australia to Antarctica, and

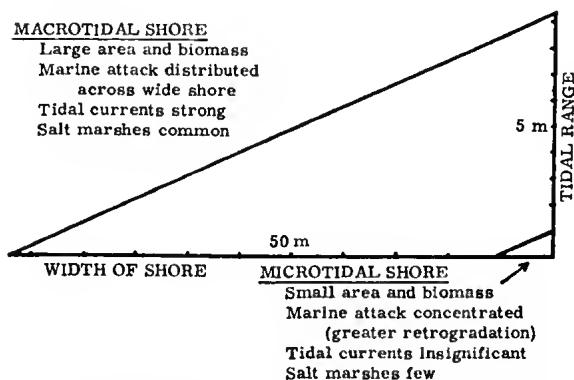


FIG. 3.—Diagrammatic presentation of the effects of microtidal as against macrotidal ranges on the coastal regime.

the coast is characterised by powerful winter storms. Even in fine weather there may be a heavy swell from the southwest. This study emphasises the need to further apply the concepts of ecology to the study of shorelines.

ECOLOGIC CONTROL OF WATER-LAYER WEATHERING

Modern shoreline studies began on the stormy macrotidal coasts of Great Britain. The power of the sea was obvious. It was considered the chief agent in coastal erosion. Later, Wentworth (1938) studied shore platforms in the lower energy tropical Hawaiian islands, and drew attention to the strong chemical weathering of the rocks by water pools (water layer weathering). Many subsequent workers have:

1. Placed these two processes in apposition. Their argument is that the chief agent of coastal reduction is not the physical power of the sea, but the chemical effectiveness of water layer weathering. The role of the sea has been played down, some regarding it merely as the transporting agent that carries away the products of weathering.

2. Regarded effective water layer weathering as a universal phenomenon, that applies as much to the temperate and frigid zones as to the tropical one where it was first described. Authors have used this process to account for shoreline phenomena in Bass Strait.

The writer (Gill 1972a) has hypothecated that *water layer weathering as originally described is a function of the chemically aggressive tropical climate, and is not significant in the temperate and frigid zones; it is a process under ecologic control.* The writer's view is that:

1. *Marine erosion and water layer weathering should not be put in apposition.* The power of the sea is obvious in quarried blocks, boulder formation high above HWL, cliff retreat, cave formation and demolition, destruction of sea walls, and wrecks. Moreover, it is a universal phenomenon varying in intensity with local climate. Thus,

water layer weathering and storm effects occur together in Hawaii. MacDonald and Abbott (1970, p. 196) record: 'Blocks of lava rock up to 12 ft long and weighing as much as 15 tons, have been thrown by waves onto the shore platform, in some places 30 ft above scalevel, along the Puna coast of the island of Hawaii.' Johnson (1919) reported water pressures measured by dynamometer along the Scottish coast of over 6000 pounds per square foot. Sparks (1960) says 'Large masses of spray have been recorded moving upwards at 70 mph, while small jets have been observed with the astonishing speed of over 170 mph.' Sussmilch (1912) gave an example of powerful wave action on the coast at Bondi in N.S.W., where a block of sandstone ~ 235 tons was 'elevated through a vertical distance of at least 10 feet, and then carried along a horizontal distance of about 160 feet', being turned over in the process. Bass Strait is stormy, and the cliffs, shore platforms, boulder beds, and such along its coasts bear witness to the power of sea.

2. *By contrast with marine erosion, water layer weathering is not universal but restricted to the tropics.* It yields a characteristic morphology of pools with vertical or undercut walls that often stand above the level of the water. Such have been described also by Kaye (1959) in Puerto Rico (wet tropics), and Guilcher (1958, Plate 1c) in Morocco. No such structures have been described from the shores of Bass Strait. The pools that do occur are no different from those beside a lake, on a road, or on the general terrain—simply depressions filled with water. Bartrum (1938) correctly commented that if the platforms he had described were a function of water layer weathering, 'then one would expect to see similar benches on the sheltered sides of outlying exposed stacks and islets; yet this is not the case on the Auckland coast.'

The only raised edges noted on Bass Strait shores are due to mineralized joints—iron oxides, pyrite and carbonates. The iron oxide ones are the commonest and on the Otway coast result from

TABLE 1

| <i>Water layer weathering in tropical climates</i> | <i>Pools on Bass Strait shore platforms</i> |
|--|---|
| 1. Stepped series of pools simulating sinter terraces in form. | Shallow localized pools. |
| 2. Flat bottomed pools. | Pools with concave floors. |
| 3. Vertical or undercut sides. | No distinctive edges. |
| 4. Rims stand above water level and are commonly covered with <i>Lithothamnion</i> | No rims and no bordering biota. |
| 5. Rapid chemical weathering in persistent pools. | No readily recognizable chemical weathering in ephemeral pools. |

oxidation of the pyrite. These ridges have nothing to do with water layer weathering as they are a function of differential erosion. Soluble rocks such as aeolianite have pools, but again they have no raised edges. The process of solution is not nearly as well developed as in tropical areas (Wentworth 1939).

On present understanding, the differences may be summarized as shown in Table 1 on previous page.

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DESCRIPTION OF PLATES

PLATE 5

Aerial oblique photograph by Keith Cecil of shore platforms at Lorne, Otway coast, Victoria, at low tide. The view is approximately NE. Note beach sand at landward edge of platform, and the subtidal extension of the platform.

PLATE 6

Boulder bed on the present shore c. 0.5 km SW. of St. George River, Otway coast, Victoria. General view (upper photo) and detail of boulders (lower photo).

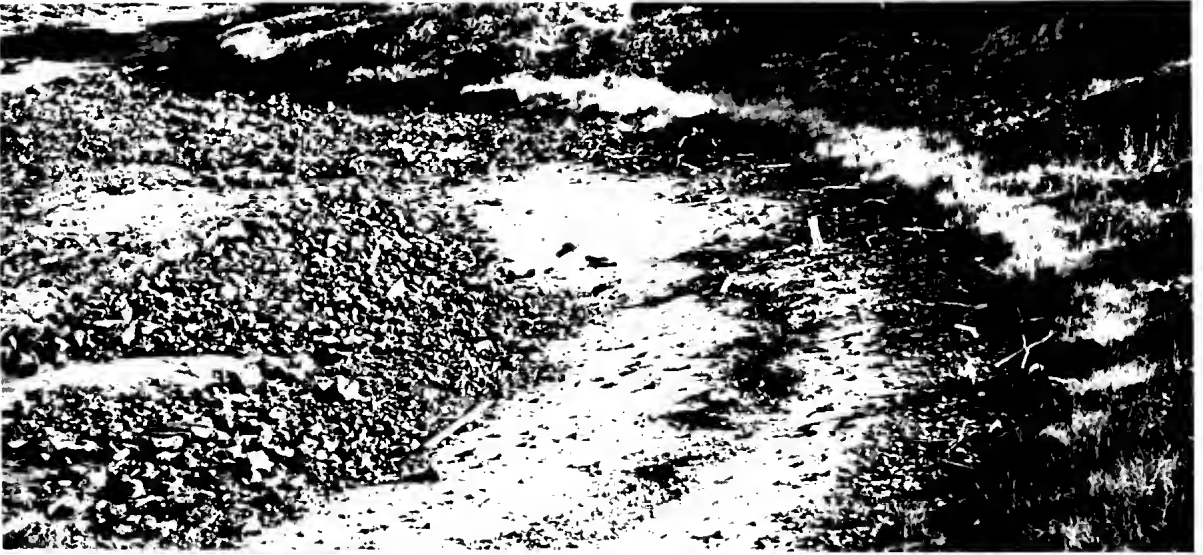
PLATE 7

Small bay SW. of Boggaley Creek, Otway coast, Victoria, showing present active boulder bed, behind which is beach, and beyond which is a Holocene boulder bed with shell; it is partly covered with flotsam but extends behind that, where it is covered with sand and vegetation, ending at a fossil cliff (upper photo).

Pleistocene boulder bed without shell in roadcut on Ocean Road c. 0.5 km SW. of St. George River, Otway coast, Victoria. It is covered by a thick bed of red colluvium (including angular rocks) which is capped by a dark gray soil (lower photo).







DEVELOPMENT OF THE GIPPSLAND LAKES ENTRANCE SINCE 1851

By J. J. FRYER*

ABSTRACT: A permanent entrance to the Gippsland Lakes was constructed during the latter half of the 19th Century, to facilitate ship access into Gippsland. A sand bar developed around this entrance on the seaward side, restricting the operation of vessels and development of the port at Lakes Entrance. The artificial entrance has also modified conditions within the lakes and caused erosion and accretion along the Ninety Mile Beach.

This paper presents a study of the major factors influencing the dynamic physical system of the Entrance region as obtained from geological and historical data, together with field and laboratory observations. Estimates are made of the magnitude and direction of littoral drift along this section of the Ninety Mile Beach.

INTRODUCTION

Since Lt. Bass first sailed into the Strait which now bears his name, this stretch of sea has been of great value in the development of Australia, providing among many other valuable resources an important transportation corridor.

Before the railways had reached into eastern Victoria, early settlers were able to ship their goods to Melbourne through the extensive river and lake systems of Gippsland and out into Bass Strait. These lakes have an area of some 40,000 ha behind the high coastal sand dunes of the Ninety Mile Beach. The lakes formerly discharged into Bass Strait at their eastern end, near Red Bluff, a 20 m high cliff located approximately 8 km E. of the present town of Lakes Entrance.

Under the influence of waves, tides and currents, the natural entrance is known to have migrated back and forth over a distance of several kilometres during the latter half of the 19th Century. The entrance also varied in both width and depth, making it difficult for sailing ships and steamers to cross the offshore sand bar and enter the lakes from Bass Strait.

After an earlier unsuccessful attempt, a permanent entrance to the lakes was created on the 14th June, 1889, but after a few years an offshore sand bar also encircled this entrance and restricted access.

With the coming of the railways to East Gippsland, the original shipping traffic declined, but the progressive development of Lakes Entrance into

one of the major fishing ports in Australia has maintained the need for a permanently deep entrance to the lakes. More recently, the discoveries of oil and natural gas offshore have attracted further interest in the port, since there are few natural harbours along this portion of the Victorian coast.

In 1963 the Public Works Department of Victoria commenced an investigation of the major factors influencing the formation of the sand bar at the entrance. This investigation included the use of hydraulic model techniques to simulate the development of the entrance bar.

DEVELOPMENT OF THE ENTRANCE

NATURAL ENTRANCE

Geologically, the Gippsland Lakes were formed during the late Pleistocene and Recent periods by the creation of successive frontal sand dunes under wind and wave action, together with comparatively minor fluctuations in sea level (Bird (1965) and Jenkin (1968)). Because the natural entrance has been located at the eastern extremity of the lakes, it has been suggested that the dominant littoral drift of beach sand in the area has been from west to east (Coode 1879) and Bird (1965, p. 95)). The magnitude and variability of littoral drift can be extremely important in the design of coastal engineering works.

The large oscillatory migration of the natural entrance in historical times suggests that the

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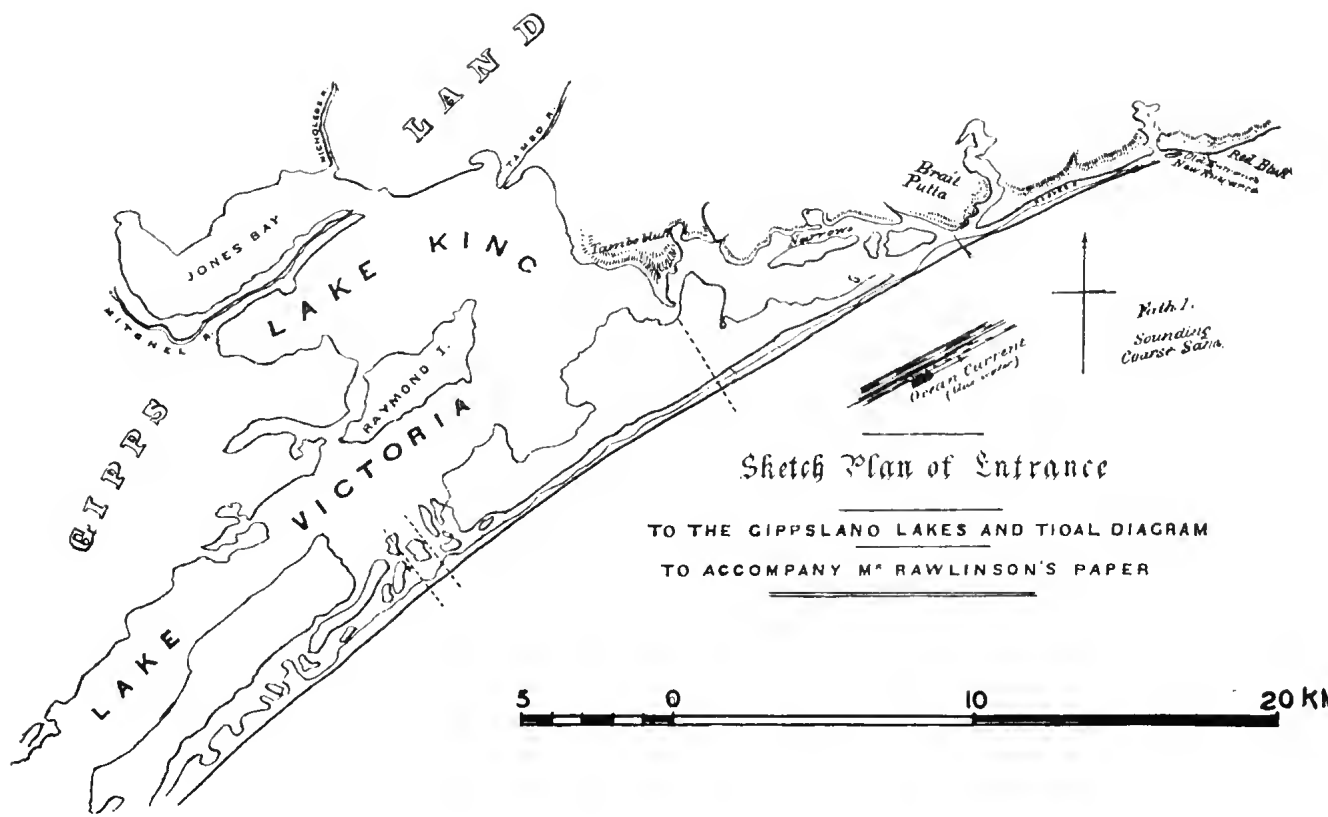


FIG. 1—Gippsland Lakes Entrance in 1863 by Rawlinson. (Courtesy of Royal Society of Victoria).

littoral drift is more nearly in dynamic balance from both directions, and large in magnitude.

Early accounts of the discovery of the Gippsland Lakes entrance were discussed by Wakefield (1969).

In 1851, G. Syme, in his Coast Survey 3A, located the then 300 m wide entrance 2.6 km west of Red Bluff. However, in a report to the Royal Society of Victoria, the Honorary Secretary, T. E. Rawlinson (1865) indicated that in 1855 the entrance was about 1.5 km west of Red Bluff but that it had gradually moved closer to the Bluff by 1862/63 when he re-inspected it. Following the drought of 1862-63 when the entrance could be crossed on foot, a flood in (mid) 1863 re-opened the old entrance and a new entrance 1/2 km to the west, but the former entrance gradually closed (Fig. 1).

Later plans show the entrance further west. A report and plan (Pl. 8) by Sir John Coode in 1879 described the migration of the entrance in the following terms:

'The position of the entrance has varied greatly from time to time. It appears, from a report by the late Captain Ferguson, that in the year 1861 the entrance

was within 200 yards of Red Bluff—the point marked X in red on Drawing No. 1—and that after remaining open there for about eight months, it began to move to the westward towards Lake Bunga, where it remained open until February, 1863, when it became nearly closed for three days, after which it broke out again and had remained open until the date of his report—2nd November, 1864.

According to information collected at the time of my examination, the most westerly position at which the entrance has ever been known is that marked by the letter Y in red on Drawing No. 1, which is about a mile further to the westward than at the time when the special survey was made in 1879.

A plan by Ferguson in October, 1864, shows both an old entrance 200 m W. of Lake Bunga and a new entrance 300 m further W. with a best navigable depth of 1.5 m below low water.

A correspondent to the *Bairnsdale and Bruthen News* on 1st July, 1889, refers to five new entrances having formed during the previous 13 years and states that the former entrances quickly closed. However, Coode refers to two navigable entrances remaining open for four months on one occasion.

TABLE 1
LOCATION OF ENTRANCE TO GIPPSLAND LAKES
1851-1879

| <i>Date</i> | <i>Distance W. of Red Bluff in m</i> | <i>Surveyor</i> | <i>Comments</i> |
|-------------|--------------------------------------|-------------------------|--|
| 1851 | 2,600 | G. Syme | Lands Dept. Coast Survey 3A. |
| 1855 | Approx. 1,500 | T. E. Rawlinson | <i>Trans. & Proc. R. Soc. Vic.</i> 6:84-90, 92-8. Entrance moving further eastward. |
| 1861 | 180 | Capt. Ferguson | Quote by Coode. Entrance stationary for 8 mths., then moved west to L. Bunga. |
| Feb. 1863 | Approx. 1,400 | Capt. Ferguson | Coode quoting Ferguson, entrance stationary. |
| Sept. 1863 | Approx. 1,400 | T. E. Rawlinson | <i>Trans. & Proc. R. Soc. Vic.</i> 6:92-8, old entrance 1/2 km further east. |
| Oct. 1864 | 1,740 | Capt. Ferguson | Chart held by PWD: shows an old entrance 1,480 m from Red Bluff, together with offshore soundings. |
| Nov. 1866 | 2,560 | | Chart held by PWD shows an old entrance 1,620 m from Red Bluff. |
| Feb. 1867 | 2,640 | Okaugtue (?) | Detailed survey of natural entrance and site of present entrance, including offshore soundings, held by PWD in two sheets. |
| Sept. 1869 | 1,840 | Lt. H. J. Stanley, R.N. | Plan of the entrance to the Gippsland Lakes showing place of proposed entrance and the prevailing winds and tides in the locality, held by PWD. Notations on sand bar around entrance refer to changeable depth and closure of entrance by strong winds with sluggish stream. Flood tide from east, prevailing breezes and gales from SW., occasional SE. gales. |
| 1871 | Approx. 2,100 | Lt. Stanley | Survey from Merriman Ck. to C. Howe, basis of Admiralty Charts. |
| 1879 | 3,300 | Sir J. Coode | Plan showing existing and proposed entrance to lakes with widest known range in location of entrance 180 m (1861) to 5,000 m from Red Bluff. |
| N.A. | Max. 5,000 | | Coode's report. |

The known locations of the entrance between 1851 and 1879 are given in Table 1.

PERMANENT ENTRANCE

In 1869, plans were prepared for the creation of a permanent entrance, 120 m wide, opposite Jemmys Point, 8 km W. of Red Bluff. Excavations through the sand dunes commenced in 1870 but were abandoned in 1874 after a heavy gale caused the excavation to be filled with sand.

After Sir John Coode's recommendation of 1879, work was resumed in 1883 on the same site and the final break-through occurred during a storm on 14th June, 1889. A Royal Commission Report (1927) incorrectly referred to the opening having occurred in 1888.

The Bairnsdale and Bruthen News on Monday, 17th June, 1889, reported on the opening and expressed the feeling of the settlers as follows:

THE NEW LAKES ENTRANCE WORKS

Success at Last

An Opening Made by the Ocean

The intelligence received on Saturday morning that the barrier (12,000 sand bags) at the new entrance works had been broken away and a deep channel formed, will be received with gratification throughout the entire province, and indeed the whole colony. There will be some surprise felt that despite the heavy rains and the consequent increased volume of water in the Lakes, the entrance was formed from the Ocean. There has been some very heavy seas prevailing along the Ninety Mile Beach for the past few days accomplished by strong westerly winds. It was to this circumstance that the breach in the barrier was due.

The sudden inrush of water from Bass Strait, which carried dredges and sand bags before it, temporarily flooded part of the township of Cunningham (Lakes Entrance). Later, the permanent entrance assisted in minimising the pre-

vious periodic flooding of the township when the natural entrance was closed.

Initially there was considerable scour within the permanent entrance channel, but a bar soon began to form in the ocean outside the entrance. The bar continued to develop, encircling the entrance and gradually moving offshore until by about 1925 it had attained a quasi-equilibrium condition. The 100 m broad bar then had a best navigable depth of around 3 m at a distance of 400 m from the head of the channel training piers.

The original training walls were constructed in timber, but the effect of teredo worms decreased their strength and the outer ends of the piers were subsequently destroyed by storms between 1897 and 1899. Stone and concrete were used to strengthen the piers between 1903 and 1913, but the original outer ends were abandoned.

Over the years, the best navigable depth across the ocean bar has frequently moved rapidly from side to side in its location and generally varied in its depth of from about 2 to 3 m below low water.

Sand has also accumulated alongside the outer faces of the two pier heads, particularly on the eastern side where the beach face has now advanced approximately 180 m and only regains its original alignment several kilometres further to the east, Pl. 9A. On the west, the beach has advanced about 100 m near the pier head, but it has eroded 150 m at a point 2 km further west and regains its original alignment some 5 km from the entrance, Fig. 2.

Assuming that the original beach alignment did not change between the survey of 1851 and when the pier heads commenced to cross the beach in 1888, the rate of erosion can be estimated from aerial photographs in 1940, 1963 and 1966. During the first 50 years, the average rate was 2.2 m per year, reducing to 1.7 m per year between 1940 and 1963. Wind fences, built on the upper beach in about 1965, appear to have arrested this erosion.

The volume of sand eroded on the western side of the entrance is estimated to be of the order of 8 million cubic metres. The volume trapped within the new entrance sand bar is about 11 million cubic metres and a further 2 million cu m has accumulated on its eastern side.

These volumes allow an estimate to be made of the total average annual littoral drift of sand from both directions along this part of the Ninety Mile Beach. If it is assumed that all the drift was trapped initially and that equilibrium was achieved over say 75 years at a uniformly decreasing rate, the average total littoral drift would be of the order of 300,000 cu m per year.

From surveys, a comparable estimate of 300,000 cu m per year for littoral drift can be made from the 1.4 million cu m of sand trapped on the bar in the 36 months immediately following the opening of the entrance, after allowing 0.4 million cu m of sand scoured out of the channel.

Sand on the Lakes Entrance bar has a median diameter of about 0.4 mm and contains only a few percent of shell. Similar sand occurs in the high

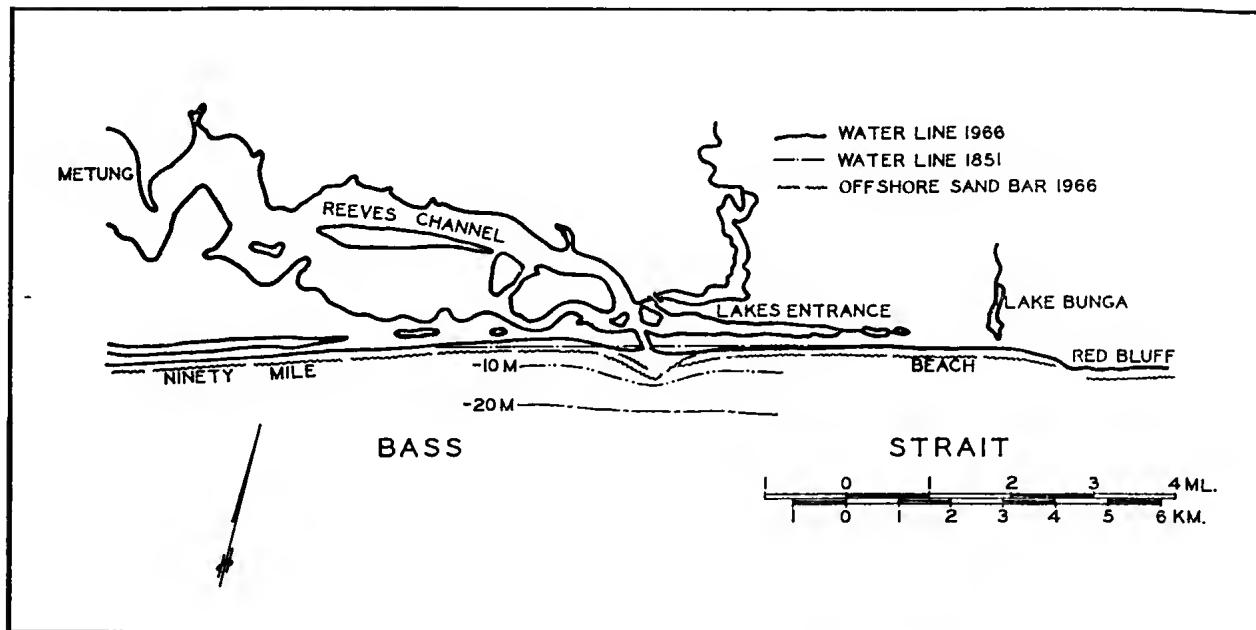


FIG. 2—Ninety Mile Beach in 1966.

wave energy zones on the beach and in the breaker zones for 10 km on either side of the entrance. Very fine sand with a median diameter of about 0.15 mm occurs in two zones situated on either side of the entrance at a depth of about 10 m. This fine sand may have come from deposits of similar sized sand which exists inside the lakes. The offshore deposits vary over several kilometres in their extent and distance from the entrance but there is insufficient data to indicate drift patterns. However, the drift of this fine sand does not necessarily correspond to the drift of the coarser sand in the surf zone.

FORCES AFFECTING THE ENTRANCE

The major forces acting on the entrance are due to waves, tides and river flows.

The average annual river discharge through the entrance is about 3.3×10^9 eu m, corresponding to approximately 100 eu m per second. Average monthly flows range from about 33 m³/s in February to about 190 m³/s in September. In severe droughts, evaporation in the lakes exceeds the river flow, causing a net inflow of water from Bass Strait, while during the major flood in December, 1934, the outflow was probably about 5,000 m³/s.

Although the tidal range in Bass Strait near Lakes Entrance is relatively small, the large area of the Gippsland Lakes subject to tidal effects causes a strong tidal flow through the entrance. The semi-diurnal tides recorded in the Cunningham Arm of the lakes, just inside the entrance, have a spring and neap range of about 0.5 m and 0.3 m respectively. In the main body of Lake King and Lake Victoria, these tides attenuate to 15% of the amplitude inside the entrance and have a phase lag of 3 hours. Offshore, the tides are estimated to have about twice the entrance amplitude. Rawlinson recorded ocean tides for several weeks in 1863 and it appears that he obtained a similar result. Ferguson's chart of October, 1864, gave a spring tidal rise above datum of 1.2 m while Coode referred to a spring tide range of 1 m.

In February, 1963, the maximum tidal velocity measured in the main entrance channel was 2.5 m/s on a spring tide, corresponding to a peak discharge of 1,000 m³/s. However, the average tidal flow over a tidal cycle is about 500 m³/s for a mean tidal range, or five times the average river flow.

The flood tide comes in approximately radially over the ocean sand bar but the ebb tide runs out as a jet from the pier heads. The ebbing current is at its maximum at low tide and these two effects accentuate the breaking of waves on the bar, bringing sand into suspension and scouring a shallow

channel through the bar. On the flood tide, some of the sand on the bar brought into suspension by wave action is carried through the entrance and deposited inside the lakes until it is returned to the bar by subsequent ebb tides.

Wave action also carries sand around the bar to maintain general continuity in the littoral drift along the coast.

Storm waves from WSW. with a maximum height of about 6 to 9 m and period of 6 to 8 seconds have been recorded offshore in the vicinity of the oil rigs, but seas with a maximum height of about 2 m are common.

Waves are refracted as they approach the shore and the daily incident wave direction on the Lakes Entrance bar has been recorded. While it is difficult to estimate wave characteristics visually, records during 1965/66 indicate that easterly waves were almost twice as frequent as south-westerly waves, while very few waves came from the S.

Wave observations are made twice daily at the lighthouse at Gabo Island and Wilsons Promontory. These waves are classified into either local wind generated seas of different heights or ocean swells from distant storms with different states of height and length.

Over the period 1960 to 1964 inclusive, half of the swell waves at Wilsons Promontory came from the SW. and a quarter from the E. From both directions, these swell waves were mostly low (0.2 m) in height with short or average length (0.2-200 m). Seas were more variable but were mainly from the W. and NE. in similar proportions. Gabo Island is more sheltered from the SW. and southerly swells dominate with 36% of the occurrences, followed by 19% from the E. and 15% from the SE. Easterly swells are more frequent in summer. However, seas from the SW. sector contributed almost half of the total occurrences followed by the NE. sector with over a quarter.

Lakes Entrance is approximately mid-way between these two lighthouses, and the offshore wave conditions will be approximately the average of the two sets of observations. Estimates of the littoral drift produced by the various groups of seas and swells can be made by assigning typical characteristics for each group and calculating the wave energy and refraction.

Swell waves at Lakes Entrance convey approximately six times more energy to the coast during the year than the local seas. In a storm, seas can be very large but they are short in duration compared with the persistent swells.

The swell wave energy from the SW. is concentrated around waves with height of 3 m and period of 9 seconds. From the E., the correspond-

ing waves have a period of about 8 seconds but are slightly higher and contain similar energies per wave. Although the south-westerly waves occur more frequently, their effectiveness in transporting sand is reduced by their angle of attack on the shore. In an earlier assessment of wave conditions, the effect of the south-westerly swells reaching Lakes Entrance from the western end of Bass Strait was under-estimated (Jenkin (1968, p. 89)).

The average littoral drift produced by all swell waves is estimated to be approximately 600,000 cu m per year, half coming from the E. and half from the W. The effect of seas would slightly increase this estimate of the littoral drift.

HYDRAULIC MODEL

A pilot hydraulic model was constructed to simulate the major effects of waves, tides and river discharge on the movement of sand in the vicinity of the entrance. The model extended over a semi-circular area of the ocean within 1.4 km of the entrance at a horizontal scale of 1:300 and vertical scale of 1:100.

Waves of different height and period were generated by a 9 m long oscillating vertical blade. Wave directions were varied by rotating the model which was mounted on a turntable. Tidal heights and currents through the entrance were simulated by a recirculating pumping system which automatically changed the tidal current direction every 12.5 minutes, representing 6.2 hours in the prototype. River flow was introduced upstream of the entrance.

A fine beach sand was employed to simulate the coarser sand at Lakes Entrance as no light-weight material was available at that time. Sand traps were located at both ends of the beach and inside the entrance. As required, sand was fed into the model at these locations.

The model commenced operation before the analysis of prototype wave data was available and the optimum test conditions to simulate known bottom configurations were obtained by trial. Frontal waves of 3 m height by 9 s period achieved a good simulation of the beach, longshore bar and bottom profile known to have existed before the permanent entrance was constructed.

After a further series of trials with the permanent entrance in position, the model was able to simulate the development of the bar and beach at the entrance from the time it was opened to its present equilibrium condition as shown in Pl. 9B.

Because of the comparatively heavy bed material in the model, it was found necessary to increase the scaled tidal and river flows to locate the entrance

bar in its correct prototype position further offshore. Acceptable entrance bar configurations and ocean beach accretion and erosion patterns on either side of the entrance were obtained with 3 m x 9 s waves applied alternatively after each tidal cycle from 10° either side of the frontal wave position.

Although equal wave energy was applied symmetrically from both directions, an asymmetrical beach alignment was created because of the oblique angle of the ebb current through the entrance.

A greater proportion of waves from either the E. or W. produced a poorer simulation of the beach alignment and bar formation. Large storm waves rapidly eroded the beach and destroyed its relatively smooth alignment as well as creating a pronounced breaker line trough in the entrance bar. With no waves, sand carried out from the lakes formed a long tongue-shaped deposit offshore to just below the low water line.

DISCUSSION

The determination of the dominant direction of littoral drift can be assessed from a number of factors, some of which appear to be in conflict in the vicinity of Lakes Entrance.

The location of the entrance to the Gippsland Lakes at its eastern extremity has been interpreted by Coode (1879) and Bird (1965, p. 45) to be due to a predominance of south-westerly wave action.

The general migration of the natural entrance over several kilometres towards the E. between 1851 and 1861 followed by a general movement towards the W., suggests that the littoral drift from both directions is more nearly in dynamic balance and large in magnitude. The present entrance also exhibits lateral fluctuations in the location of the best available depth for navigation.

The natural entrance was also located in the curved transition between two generally long straight coast alignments extending from near Port Albert in the W. to Point Hicks in the E.

Usually, the creation of a barrier across a beach causes an accumulation of sand on the updrift side and erosion on the downdrift side. This erosion and accretion continues until a new stable alignment is established when the continuity of drift is restored. At Lakes Entrance, the large accretion on the eastern side of the permanent entrance, together with the large erosion of the W. suggests that the dominant drift has been from the E. over the past 80 years. This is also supported by the alignment of the beach just E. of Red Bluff being further advanced offshore than the beach just W. of the Bluff. Several small lakes and rivers further

to the E. of Red Bluff also tend to have their mouths located at the western end of ocean sand-pits.

Although in the model the tidal current effects were exaggerated, the results indicated that the accretion and erosion along the ocean beach near the entrance need not be due to a dominant littoral drift from the E. but arise from the oblique orientation of the entrance channel, coupled with a balanced littoral drift from both directions.

Estimates of littoral drift based on wave analysis further support the concept of a balance between the drift from both directions at Lakes Entrance.

Three estimates of the magnitude of the total littoral drift based on the initial rate of deposition of sand at the permanent entrance, the longer term changes in volume and the wave energy analysis all indicate a large drift of the order of 300,000 cu m per year.

CONCLUSIONS

The entrance into the Gippsland Lakes from Bass Strait has continued to be a significant factor in the development of this region of Victoria.

The location, size and number of natural entrances changed frequently prior to the construction of the permanent entrance in 1889.

Since 1889, the Ninety Mile Beach has been eroded on the western side of the permanent entrance and sand has deposited around the entrance, particularly on the eastern side, and offshore where a bar has developed.

At present, the entrance region has achieved a new equilibrium situation and the estimated total annual littoral drift of about 300,000 cu m is considered to have been derived approximately equally from the E. and W. Wave action is the dominant force controlling the depth of water on the bar while the distance offshore is mainly dependent on the current through the entrance.

Further from the entrance on both the eastern and western sides, the net littoral drift is likely to be towards the entrance.

ACKNOWLEDGMENTS

The author wishes to thank the Public Works Department of Victoria and the State Electricity Commission of Victoria for permission to publish this paper. The work was commenced during his period of employment with the Public Works Department and completed after he joined the State Electricity Commission.

Thanks are also expressed to the Royal Society of Victoria and the Department of Crown Lands and Survey for permission to include copies of their plans and photographs.

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DESCRIPTION OF PLATES

PLATE 8

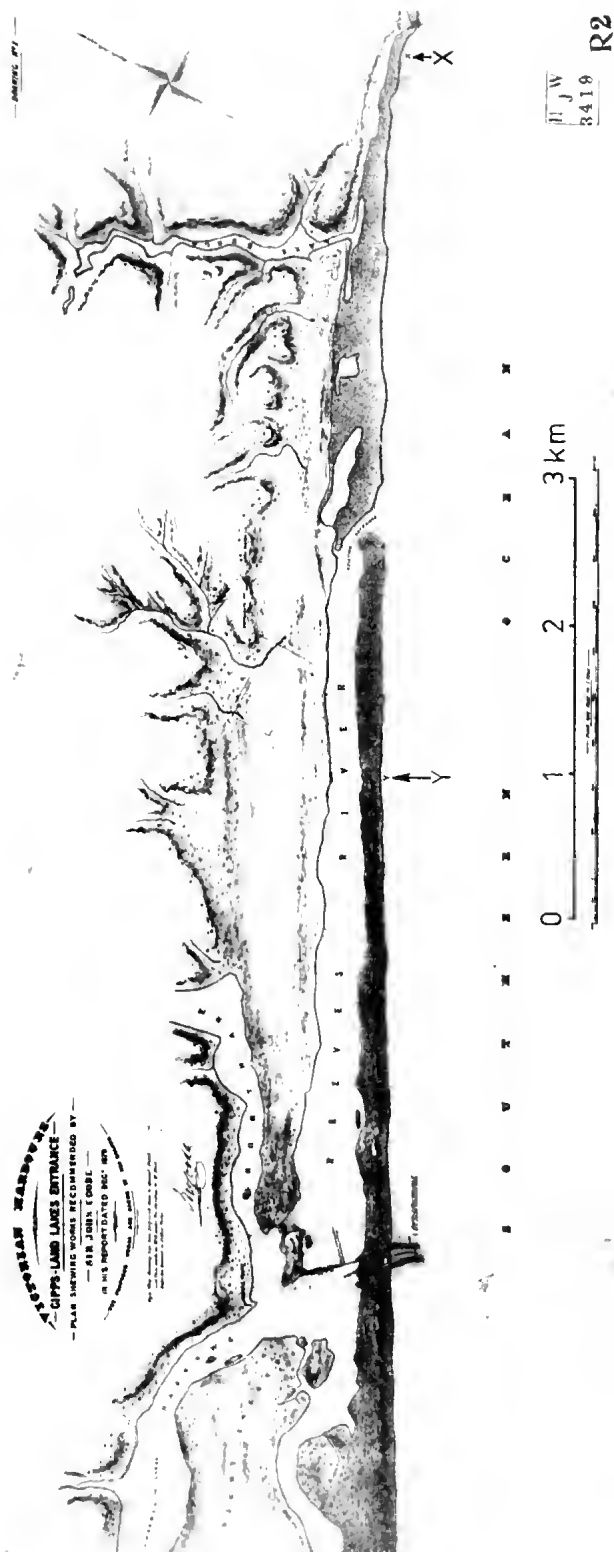
Gippsland Lakes Entrance in December, 1879 by Coode. This is a 7:1 reduction of the original pen-line drawing with water-colour tints on linen-backed paper, held by the Public Works Department. (Courtesy of Public Works Department of Victoria).

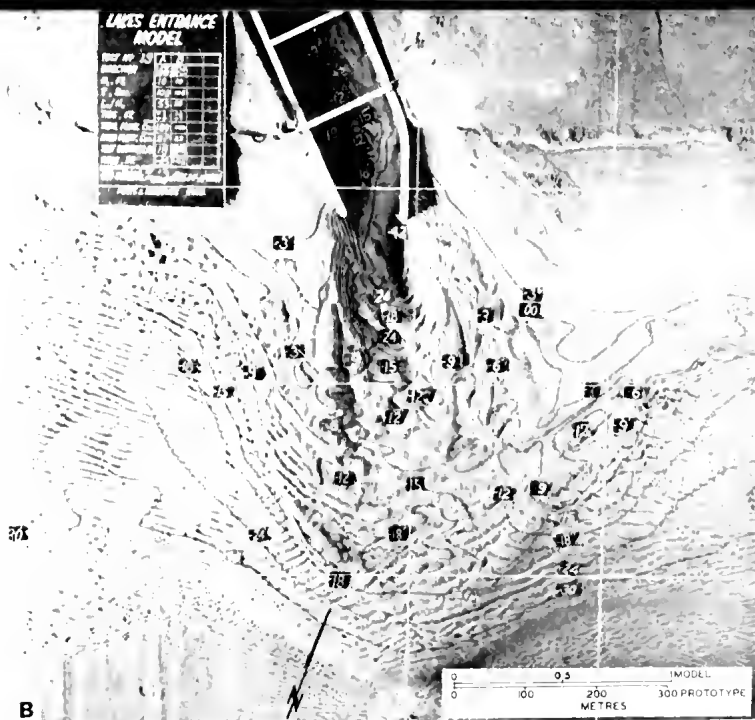
PLATE 9A

Entrance, February 20, 1963. (Courtesy of Department of Crown Lands and Survey).

PLATE 9B

Model Simulation of Present Entrance Conditions. (Courtesy of Public Works Department of Victoria).





THE GEOLOGICAL DEVELOPMENT OF THE SOUTHERN SHORES AND ISLANDS OF BASS STRAIT

By F. L. SUTHERLAND*

ABSTRACT: The geology of the Tasmanian margins and islands of Bass Strait is reviewed in the light of recent work. Since its inception, the Bass Basin has played an important role in the geological development of the uplands. The later structure was probably inherited from mid-Jurassic times when intrusion of dolerite sheets uplifted the southern margin. Its early development as an *en echelon* graben was linked with spasmodic magmatism on the uplands, this igneous activity continuing into mid-Cretaceous times.

The main outlines of Bass Basin and associated upland troughs had formed by faulting by Paleocene times and thick sequences of non-marine sediments accumulated in these depressions. By late Eocene times restricted seas entered the basin, major faulting ceased and basic volcanism broke out along the Tasmanian uplands. Some upland troughs had become choked with thick sequences of subaerial lavas by late Oligocene times.

Miocene marine transgression onto Tasmania was impeded in troughs containing the older basaltic fills, but where the seas coincided with concurrent volcanism, the finest range of aquagene volcanic sequences known in the Australian Cainozoic formed up to heights over 120 m above present sea-level. The vigorous mid-Cainozoic volcanism produced both alkali basaltic and tholeiitic lavas and considerable volcanism also occurred following regression of the Miocene high seas and dissection of its deposits. The precise age of the later volcanism presents a problem still to be solved. The distribution of the Tertiary magma types appears to be structurally controlled with tholeiitic rocks developed over mantle upwarps along margins of the basin.

Since mid-Pliocene times at least, the Tasmanian margin of Bass Strait appears to have remained tectonically and volcanically relatively inactive. The later history has been mainly one of eustatic fluctuations controlling coastal depositional and erosional processes, particularly during glacial and interglacial phases. Old strand line deposits, largely related to interglacial higher seas, have been recognized up to heights of 45 m above present sea-level. Glacial meltwaters contributed cobble deposits at the outlets of the Mersey and Forth Rivers. Extensive dune building, both siliceous and calcareous in nature, has invaded favoured locations and since the rise of the post-Glacial sea well developed beach ridge systems have formed in some areas. The sea-level fluctuations influenced distribution of animal populations on Bass Strait coasts and isolated the Tasmanian Aborigine.

INTRODUCTION

Bass Strait extends over a major structural depression, the Bass Basin, which separates Tasmania from Victoria (Jennings, J., 1959a; Richards & Hopkins, 1969). This structure has strongly influenced the later geological history of north Tasmania as an outlet for major drainage, as a region of marine incursions and as a locus of igneous intrusion and volcanism. Bass Strait provides an extensive margin for coastal dune and

littoral deposits and fluctuations in sea-level have regulated movements of land animals across it.

The first extended survey of the Tasmanian margin (Stephens, 1909) included a strip map of the coastal geology from the Tamar to Circular Head. Recent work now furnishes much new detail and understanding of the geological development of the shores and islands. The area considered in this paper (Fig. 1) is covered in its central part by the Geological Survey 1" to 1 mile (1: 63,

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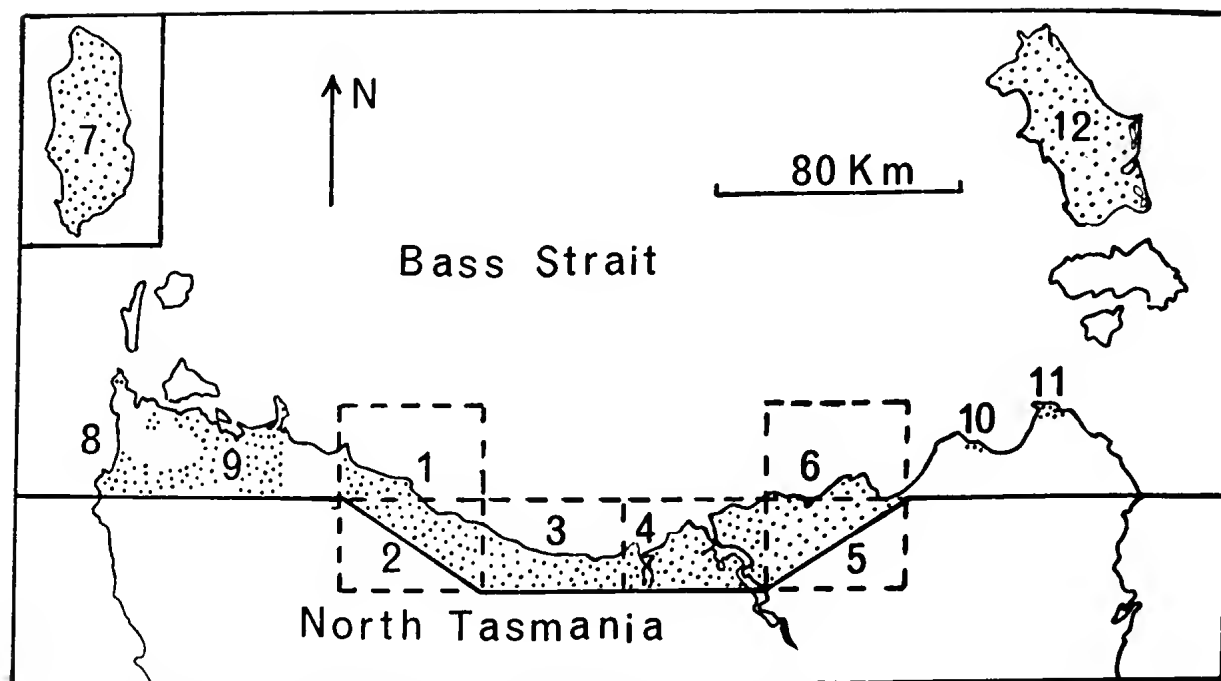


FIG. 1—Map showing islands and shores of southern Bass Strait. The area considered in the text lies above the thick line. Areas within, that are covered by recent published geological mapping (stippled zones), include 1" to 1 mile (1: 63,360) Sheets (1) Table Cape, (2) Burnie, (3) Devonport, (4) Beaconsfield, (5) Pipers River, (6) Noland Bay, and other mapping, (7) King Island, (8) Woolnorth-Marrowah, (9) Smithton, (10) Tomahawk, (11) Cape Portland, (12) Flinders Island.

360) mapping of the following sheets: (1) Table Cape (Gee, 1971); (2) Burnie (Gee et al., 1967); (3) Devonport (Burns, 1964); (4) Beaconsfield (Gee & Legge, 1971); (5) Pipers River (Marshall et al., 1969); (6) Noland Bay (Jennings, D., 1967). Further published mapping covers some other parts, namely: (7) King Island (Jennings, J., 1959b; Solomon, 1969); (8) Woolnorth (Sutherland & Corbett, 1967); (9) Smithton (Gulline, 1959); (10) Tomahawk (Moore, 1969); (11) Cape Portland (Jennings, D. & Sutherland, 1969); (12) Flinders Island (Sutherland & Kershaw, 1971). Unpublished mapping of several areas is also available and includes Clarke and Cape Barren Islands (J. Coeker, Ph.D. in prep., University of Tasmania) and bed rock geology of the Blue Tier Batholith (D. I. Groves) and the Tomahawk-Mt. Cameron area (D. I. Groves & D. J. Jennings, Tasmanian Mines Dept.).

Off-shore stratigraphic information within the Tasmanian part of the Bass Basin includes petroleum exploration drilling (e.g. Bass 1, 2 & 3; B.M.R. Petroleum Search Subsidy Rept. No. 83, 1965-1967). In the light of new data briefly incorporated in this paper previous correlations of sedimentary and volcanic Cainozoic successions

along Bass Strait shores in northern Tasmania (Sutherland, 1969a) need some revisions, and these will be presented in detail elsewhere (Sutherland, in prep.).

The area is of economic importance and information of economic geological interest appears in unpublished reports by lease and exploration licensee holders, held in the records of the Tasmanian Mines Dept. Tungsten and heavy mineral sands are worked on King Island (Knight and Nye, 1965; Jennings, I. et al., 1967), there are gold and tin deposits in north and north-east Tasmania (Noldart & Threder, 1965; Jack, 1965, 1966; Jennings, I. et al., 1967), but petroleum prospects in the Bass Basin are yet to be realized (Hopkins, 1966; Richards & Hopkins, 1969).

The margins of Bass Basin were initiated following tensional rupturing of eastern Gondwanaland in the mid-Mesozoic, contemporaneous with orogenesis along the continental margin (Griffiths, 1971). The thick dolerite sheets of Tasmania appear to terminate in southern Bass Strait. Dilation associated with their intrusion probably contributed to uplift of the southern margin. The dolerite invasion (165 m.y.; McDougall, 1961) marks a convenient event, dividing the geological develop-

ment of the Tasmanian block into pre- and post-Bass Basin rocks.

PRE-BASS BASIN BASEMENT

This includes (i) Precambrian and Palaeozoic rocks that preceded the Tabberabberan Orogeny (about mid-Devonian; Spry & Banks, 1962), (ii) Upper Devonian to Lower Carboniferous post-orogenic granites (McDougall & Leggo, 1965), (iii) Upper Carboniferous to Lower Jurassic sedimentary cover and (iv) the mid-Jurassic dolerite intrusions.

Precambrian

Proterozoic rocks outcrop extensively on the NW. Coast and the islands (Jennings, J., 1959b; Gulline, 1959; Burns, 1964; Sutherland & Corbett, 1967; Solomon, 1969; Gee, 1971). They are largely unmetamorphosed successions of quartzose sandstone, siltstone, quartz wacke and minor lavas, traversed by subordinate belts of metamorphosed rocks that include quartzite, schist, amphibolite and stretched conglomerate. The Keith Metamorphics at Wynyard overlie and separate the Rocky Cape Group (5,730 + m thick) from the younger onlapping Burnie Formation (4,400 + m thick and formed in a separate depositional basin) and probably represent a high angled shear zone (Gee, 1968). Relationships of the Ulverstone and Forth Metamorphics are less clear and they may unconformably underlie the sedimentary successions (Burns, 1964). On west King Island, the beds are intruded and contact metamorphosed by granite at least 750 m.y. old (McDougall & Leggo, 1965). Doleritic and meta-doleritic dykes and sills dated to about 700 m.y. were intruded into the Rocky Cape Group and Burnie Formation contemporaneously with folding (Cooee Dolerite and Penguin Orogeny; Spry, 1957, 1962; McDougall & Leggo, 1965; Gee, 1971).

Fold styles in the successions are broad and open to overturned and are broken by Precambrian high angle NE.-SW. thrusts and major E-W. transcurrent faults from Rocky Cape to Ulverstone. They show regional strikes trending from N.-S. (King Island, Hunter Island, Woolnorth) to NE.-SW. (Rocky Cape Group and Burnie Formation) and NW.-SE. at Badger Head. Recent mapping of Hunter Island (D. J. Jennings & F. L. Sutherland) shows that it consists entirely of largely unmetamorphosed Precambrian slate, siltstone, quartzose sandstone and rare dolerite dykes, folded into a broad domal structure elongated N.-S. and affected mainly by meridional faults.

Dolomites with thin basal conglomerates (900

+ m thick) transgress onto the Rocky Cape Group around Smithton and are usually included in the Precambrian (Gulline, 1959; Spry, 1962; Gee, 1968), but may be early Cambrian. Conversely, some beds (with some dolomitic horizons) which are grouped with Cambrian successions, as at King Island and Port Sorell, may be Upper Precambrian (McDougall & Leggo, 1965; Gee & Legge, 1971).

Cambrian

Stratigraphically complicated, predominantly eugeosynclinal Cambrian successions occupy almost meridional depositional troughs on south-east King Island (Solomon, 1969), around Smithton (Gulline, 1959), between Penguin and Ulverstone (Dial Trough, Burns, 1964) and at Port Sorell and Beaconsfield (Gee & Legge, 1971).

The thick sequences (up to 3,230 + m thick) include greywacke, siltstone, breccia, conglomerate, chert and basic to acid volcanic and intrusive bodies. Tilloids and pillow lavas occur on King Island and mega-breccias, chaos structures and pillow lavas occur in the Dial Trough. Beds within these sequences have been dated on marine faunas from late Middle Cambrian to late Cambrian at Smithton, Dial Trough and Beaconsfield (Banks, 1962). Late (?) Cambrian serpentized and albitised ultramafic and mafic complexes intrude Cambrian and Precambrian rocks at Beaconsfield and between Forth and Ulverstone (Burns, 1964; Gee & Legge, 1971). Unconformities found between some of the successions and the overlying Ordovician suggest that they were folded in the late Cambrian to early Ordovician Jukesian Orogeny. Solomon and Griffiths (1972) have recently suggested that such movements and deposition of overlying conglomerate wedges may have resulted from the collision of the Precambrian blocks along the line of the main Cambrian volcanic arc, due to westward movement along a subduction zone. However, other possibilities are equally feasible on present evidence.

Ordovician-Lower Devonian.

West of the Tamar, folded Ordovician sediments of the Junee Group (almost 1000 m thick) occur at Beaconsfield, Melrose and Dial Range (Burns, 1964; Gee & Legge, 1971). The lower siliceous rocks pass from terrestrial fanglomerates to marine miogeosynclinal sandstone and limestone, dated on marine faunas from Lower to Upper Ordovician (Banks, 1962b).

East of the Tamar, the Mathinna Beds outcrop extensively through to NE. Tasmania and the Furneaux Islands (Jennings, D., 1967, Marshall et al. 1969; Gee & Legge, 1971; Sutherland &

Kershaw, 1971). The Beds represent deeper water lutites and turbiditic arenites, dated on sparse fossil evidence from Lower Ordovician to Lower Devonian (Banks, 1962c; Marshall et al., 1969; Strusz, 1972). They show low grade metamorphism developed with tight and overturned folding. NW.-SE. regional fold trends change to NE.-SW. trends on Flinders Island, similar to the offshore regional Palaeozoic trends in Bass Strait (Hocking, 1972, Fig. 2). Both the June Group and Mathinna Beds were folded during the Tabberabberan Orogeny, which Solomon and Griffiths (1972) suggest was probably related to collision between the Ordovician-Devonian continental margin and the Lord Howe block.

Upper Devonian-Lower Carboniferous

Post-orogenic granitic bodies intrude the folded basement rocks on King Island, Three Hummock Island and in batholithic dimensions in north-east Tasmania, from Scottsdale to the Furneaux Group and other islands on the Bassian Rise (McDougall & Leggo, 1965; Marshall et al., 1969; Sutherland & Kershaw, 1971). Radiometric K/Ar and Rb/Sr dating indicates Upper Devonian intrusive ages at Scottsdale and Clarke Island (370 ± 10 m.y.) and Lower Carboniferous ages ($354-335 \pm 5$ m.y.) on Cape Barren, King and Three Hummock Islands (McDougall & Leggo, 1965; Tasm. Mines Dept., rept. in prep.). Contact metamorphic and mineralized aureoles are well developed on some granite margins (Marshall et al., 1969; Large, 1971) and late-stage doleritic dyke swarms of related age are commonly associated with the north-east granites.

Upper Carboniferous-Triassic

Near horizontal beds unconformably overlie the folded basement or eroded granite around Wynyard, Devonport, Tamar Valley and Gladstone (Burns, 1964; Gee et al., 1967; Gee & Legge, 1971). Basal Wynyard Tillite (300 + m thick) of possible Carboniferous age gives way to Permian marine beds (450 + m thick) containing freshwater horizons. These pass up into Triassic freshwater sandstones and shales in the Tamar Valley.

Jurassic

Sheets of tholeiitic dolerite, some greater than 200 m thick, intrude Permo-Triassic beds at Devonport, Tamar Valley, Waterhouse, Cape Portland and some off-shore islands (Burns, 1964; Jennings, D., 1967; Moore, 1969; Jennings, D. & Sutherland, 1969; Gee & Legge, 1971). The only direct evidence supporting the supposed

Jurassic age is at Cape Portland, where the dolerite is cut by and disconformably overlain by Lower Cretaceous igneous rocks. Feeder sources for the dolerite have been suggested near Dulverton, south of Port Sorell, Sidmouth, Tomahawk and off Cape Portland (Burns, 1964; Jennings, D. & Sutherland, 1969; D. E. Leaman, pers comm.).

POST-BASS BASIN HISTORY

Late Mesozoic Tectonism and Igneous Activity.

Major Upper Jurassic rifting, sedimentation and basic magmatism along the Otway Rift Valley, initiated the tectonic activity from which the Bass and Gippsland Basins later originated as subsidiary *en echelon* grabens within the cratonic highs (Richards & Hopkins, 1969; Griffiths, 1971; Hocking, 1972). The strong north-westerly rifting which formed the Bass Basin, was accompanied by spasmodic late Jurassic to mid-Cretaceous potassic magmatism. This is represented by basic minettes on King Island (137 m.y.), by the K-rich porphyrites, lamprophyres and subaerial lavas at Cape Portland (91-103 m.y.) and possibly by trachytic rocks in Bass 2 well (McDougall & Leggo, 1965; Jennings, D. & Sutherland, 1969; Sutherland & Corbett, 1972; Sutherland, 1972b). Pre-Upper Cretaceous sediments probably occur in some of the earliest Bass Basin rifts (Richards & Hopkins, 1969). It might be expected that they contain igneous debris supplied from the adjacent igneous activity, as occurs in the U. Jurassic/L. Cretaceous Strzelecki Group in the Strzelecki Basin (Hocking, 1972).

Following the partial detachment of Tasmania during separation of the Australian and Antarctic cratons in the mid-Cretaceous (Griffiths, 1971), the potassic magmatism ceased. Widespread faulting and subsidence formed the main outlines of the Bass Basin as sea-floor spreading opened the Tasman Sea to the E. (80-60 m.y.; Hayes & Ringis, 1972a).

Early Tertiary Tectonism and Sedimentation

Large scale faulting had broken across the southern Bassian uplands by early Tertiary time, to form NW. trending rift wedges and grabens such as the Mersey and Tamar Structures (Burns, 1964; Gee & Legge, 1971; Sutherland, 1971a). These depressions formed major drainage outlets joining Bass Basin and became catchments for non-marine sediments, which fill them to at least 518 m at Pardoc Beach, 335 m at Port Sorell and 300 m in the Tamar Trough (Longman & Leaman, 1971). Recent geophysical work suggests that a further NW. trending filled graben, at least 600 m

deep, intersects the NE. coast near Gladstone (D. E. Leaman, pers. comm.). There are also suggestions of strong EW. cross faulting down-stepping the coastal dolerite northwards along the SE. margin of the Bass Structure (see rock distribution in mapping of Moore, 1969; Jennings, D. & Sutherland, 1969; Jennings D., 1967), while cross-faulting on the Bassian Rise probably bounds the Furneaux Islands (Jennings J., 1959a; Kershaw & Sutherland, 1972). Judging from strong alignments of coastal volcanic fissures, NNW. faulting probably also bounds far north-west Tasmania (Sutherland, in prep.), terminating the western uplands against the King Island Ridge.

At the time of this faulting, the climate was conducive to lateritization and bauxitization of the upland surfaces, remnants of which are preserved on fault margins in the Tamar Trough underlying Paleocene and later sediments (Gee & Legge, 1971; Sutherland, 1971a).

The early sedimentation in the fault troughs formed an extension of the basal non-marine sedimentary complex of Bass Basin (Eastern View Complex, U. Cretaceous to lowermost U. Eocene; Richards & Hopkins, 1969); Paleocene to Upper Oligocene palynological dates are known in the Tamar Trough beds (Sutherland, 1971a). Major faulting bounding the Bass Basin ceased by early Eocene times, when Tasmania formed part of the Australian craton and active sea-floor spreading from Antarctica commenced about 55 m.y. ago (Griffiths, 1971; Weissel & Hayes, 1972). A marine basin interfingering with the non-marine sedimentation on the upland margins became fully established in the Bass Basin in late Eocene times and restricted transgressive seas deposited 150 + m of sediments (Richards & Hopkins, 1969).

Early to Mid-Tertiary Volcanism and Sedimentation.

With the onset of basic volcanism, lavas began to fill some of the drainage into the Bass Basin. The oldest identified eruptions form a sequence of subaerial alkali basalts (with olivine nephelinite) at East Devonport. Here, thin interbasaltic sediments below the top flow on the foreshore show a microflora apparently older than the mid-Tertiary *Cyathacidites annulata* flora, but lacking all the characteristic Eocene *Proteacidites* spp., suggesting perhaps an U. Eocene to L. Oligocene age (W. K. Harris, pers. comm.). These basalts fill the Devonport Lead on the west side of the Mersey Graben. Flows may have spilled from or into the Northdown Lead, where the basaltic fill is overlain by U. Oligocene beds and intercalated basalt of the Wesley Vale Lead (Burns, 1964; Sutherland, 1969a).

The Tamar basalts (Sutherland, 1969b, 1971a) and the lower valley-filling flow at Burnie (Gee et al., 1967) overlie non-marine beds that extend below sea-level and contain mid-Tertiary *C. annulata* microfloras (W. K. Harris, pers. comm.). Unpublished palaeomagnetic data on the lower Tamar basalts (Wyatt, 1971) suggests Lower Tertiary eruptive ages which place this phase of sedimentation and volcanism in late Oligocene times. Other eruptions probably of comparable age include the coarse lava of The Nut and the lower basalts at Dial Point, Don Heads, Doctors Rocks and Woody Hill Point (based on palaeomagnetic data and/or stratigraphic position below lowermost Miocene marine beds; Gee et al., 1967; Gee, 1971, Wyatt, 1971). Thus, by late Oligocene time vigorous volcanism, both alkali basaltic and tholeiitic in character, had choked valley outlets from Circular Head to the Tamar Valley with flow sequences up to 200 m thick.

Miocene Marine Sedimentation and Volcanism

Marine transgressions on southern Australian margins flooded the Bass Basin in the Miocene, forming Bass Strait and depositing 900 + m of calcareous sediments in the basin and overlapping onto the uplands (Richards & Hopkins, 1969). Shallow, warm water marine beds are preserved up to 94 m above present sea-level on King Island, and at Cape Grim, Marrawah, Redpa, Montagu, Wynyard, Somerset, Cape Portland and Furneaux Islands (Hughes, 1957; Jennings, J., 1959b; Gulline, 1959; Spry & Banks, 1962; Quilty, 1965; Sutherland & Corbett, 1967; Gee et al., 1967; Sutherland & Kershaw, 1971; Gee, 1971; Quilty, 1972). The earlier subaerial basaltic fillings along the NW. coast were apparently sufficiently thick to block entry of the transgressive seas to many of the major valleys as they show an antipathetic distribution to occurrences of the marine beds (Fig. 2). A similar situation may have existed along much of the NE. coast, but lack of firm dating of these valley fills and widespread Quaternary coastal deposits in non-basaltic embayments obscure the picture. Around Cape Portland, where both subaerial basalts and off-shore marine and on-shore lagoonal (?) Miocene beds are known (Jennings, D. & Sutherland, 1969; Quilty, 1972), stratigraphic relationships and strong induration of marine rocks tentatively suggest some marine transgression prior to any blocking extrusions.

Extensive horizons of non-marine beds, above present sea-level and commonly separating the earlier basalts from later series, are widespread in the main leads from Smithton to Port Sorell, where they form the Wesley Vale Sand (Burns, 1964;

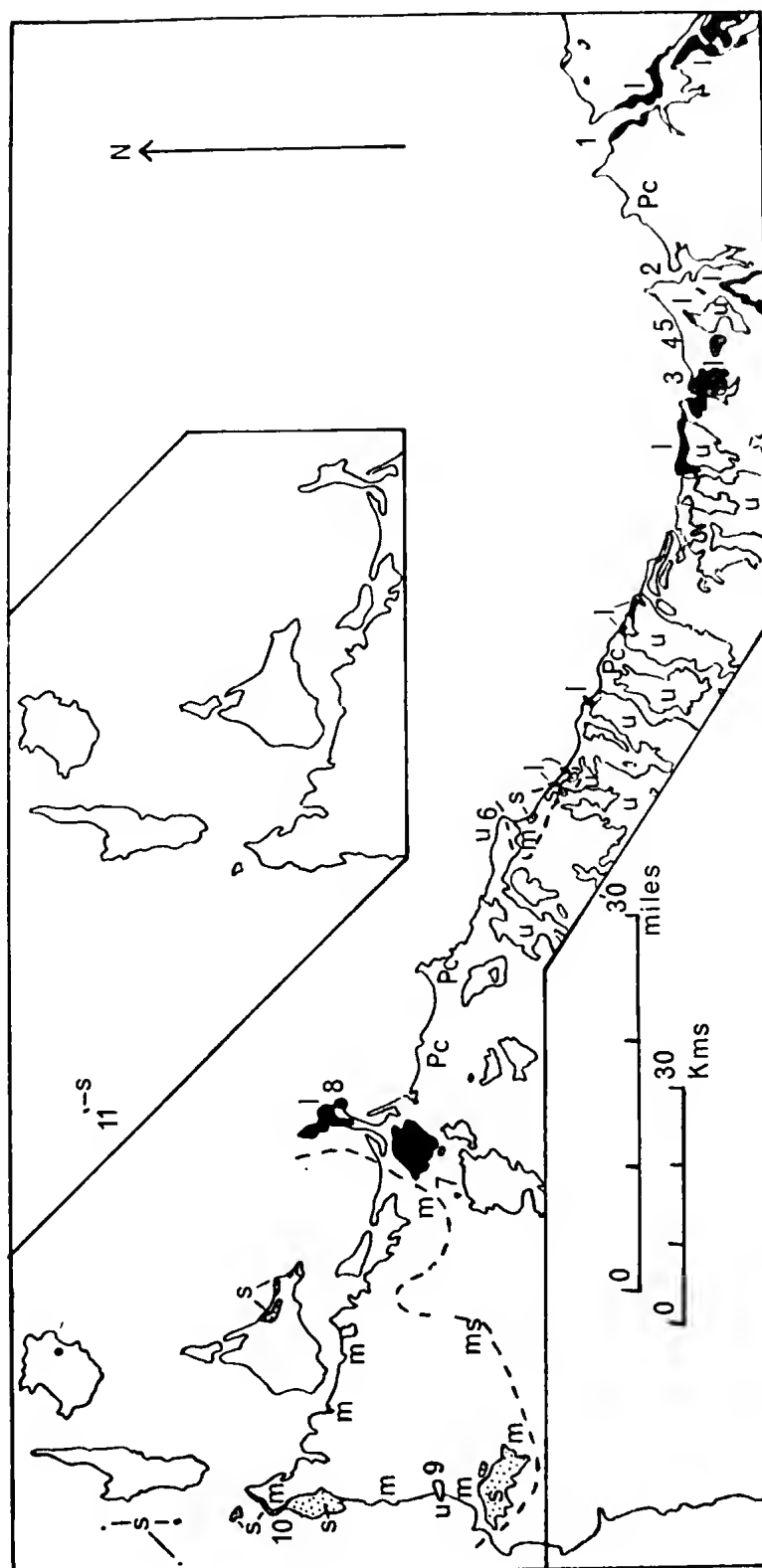


FIG. 2.—Map of north-west Tasmania showing known age distribution of volcanic sequences as Lower Tertiary subaerial lavas (black, 1), Miocene subaqueous lavas (stippled, s) and Upper Tertiary and undifferentiated subaerial lavas (clear, u) and showing their relations to known Miocene marine beds (m) and rocky headlands of Precambrian rocks (Pc). The dashed line indicates the approximate southern limits of the Miocene marine transgression onto the Tasmanian coast. Some important localities described in the text include (1) Tamar lead, (2) Sorell lead, (3) Devonport lead, (4) Northdown lead, (5) Wesley Vale lead, (6) Table Cape, (7) Lileah, (8) The Nut, (9) Mt. Cameron West, (10) Cape Grim-Studland Bay, (11) Black Pyramid.

Gee et al., 1967; Gee, 1971). At Lileah, sub-basaltic sediments of this horizon, dated as mid-Tertiary, also contain planktonic microfloras of marine or brackish water origin (Harris 1968). Thus, these horizons occupy a similar elevation and stratigraphic interval, at least in part, to the Miocene marine beds and represent equivalent on-shore facies. They provide a useful interval to separate the early and late Tertiary volcanism.

In the areas of marine inundation, particularly in north-west Tasmania, its coincidence with continued prevalent volcanism, commonly tholeiitic in character, produced extensive submarine and coastal island eruptions (Sutherland & Corbett, 1967; Sutherland, in prep.). These provide the best range of Cainozoic aquagene volcanics known in Australia. Pillow (flow foot) breccias directly overlie the lowermost Miocene marine beds at Fossil Bluff, Doctors Rocks and Woody Hill, suggesting eruption into the early Longfordian seas at levels exceeding 75 m above present sea-level. At Cape Grim, early Longfordian marine beds overlie extensive hyaloclastites, pillow lavas and pillow breccias which extend 9 km along the coast to Studland Bay and suggest eruptions into seas at least 110 m higher than present sea-level. Around Marawah and Redpa, late Longfordian to Batesfordian limestones widely underlie, but also contain older fragments of pillow breccias that were erupted into the Miocene seas to levels exceeding 120 m above present sea-level. At Brittons Swamp, a hyaloclastite basalt neck that contains fragments of Upper Longfordian marine beds, presumably erupted into the highest mid-Miocene sea. Similar aquagene volcanics occur on Robbins, Trefoil and Steep Islands, North and South Black Rocks, Black Pyramid and in the 'tuffite' cones in the mid-Tertiary marine sequence in Bass 2 well. They represent further volcanism, presumably mostly in high Miocene seas, erupting largely from NW. trending fissures. Black Pyramid, in particular, appears to show a classical sequence of an emerging volcanic island, with lower columnar pillow lavas underlying bedded 'tuffs' and capping flow foot breccias, indicating seas at least 73 m above present level.

Late Tertiary Erosion, Volcanism and Sedimentation

Marine regression in the Miocene and early Pliocene rejuvenated the upland drainage, which strongly dissected the earlier high-level sediments and volcanics and formed outlets extending below present sea-level. Continuing eruption of extensive lavas formed thick, subaerial, predominantly alkali basalt, valley-fills such as those at Mt.

Cameron West, Woolnorth Point and the broad lava plains along the NW. Coast from Smithton to Northdown (Gulline, 1959; Burns, 1964; Sutherland & Corbett, 1967; Gee et al., 1967; Gee 1971). Minor, basal flow foot breccias to these flows at Chambers Bay and Northdown Beacon may represent eruption into locally dammed drainage rather than into Miocene seas. Precise upper ages of these lavas are not known, but the deeply weathered and lateritized surfaces developed on them suggest that most, at least, are older than mid-Pliocene. An interesting problem arises in the relation of these lavas to the Miocene marine beds. Did the erosion and basaltic filling of the valleys post-date the early to mid-Miocene marine sedimentation on the uplands, or did some or all of it occur during a regressive phase within the Miocene marine transgression? A possible mid-Longfordian marine regression has been suggested by Quilty (1972). Precise dating of flows such as those at Mt. Cameron West and Table Cape, which cap dissected lowest Miocene marine beds to below sea-level, will be critical in resolving this problem.

Traces of benching on Bass Strait Island coasts at the 60-75 m levels may record old marine levels, possibly dating back to the Miocene high seas (Jennings, J., 1959b; Kershaw & Sutherland, 1972). There is no direct evidence of later Tertiary marine transgressions on inner Bass Strait margins, but shallow transgression is suggested by Middle to Upper Pliocene marine beds up to 6.5 m in elevation on the east coast of Flinders Island (Cameron Inlet Formation; Sutherland & Kershaw, 1971). Palaeotemperature measurements on shells from this formation indicate sea temperatures up to 16.5°C, but cooler than the more tropical Miocene seas (Dorman, 1966; Quilty, 1972). Lateritic surfaces on the Lower Coastal Surface in north-west Tasmania (Davies, 1959) are developed on the Upper Tertiary basalts and this lateritization probably took place under pluvial tropical conditions which apparently existed until mid-Pliocene times.

Summary of Volcanism

The structural development of Bass Strait obviously influenced Cainozoic volcanism and the basalt distribution in Tasmania broadens northwards to encompass the whole length of the Bass Strait margin. A grandiose concept of a great central volcano occupying Bass Strait and issuing flows down into the peripheral Tasmanian valleys (Noetling, 1911, Pl. 11 Fig. 3) is now easily dismissed and a number of eruptive centres have been identified along the coast (Fig. 3). Some of

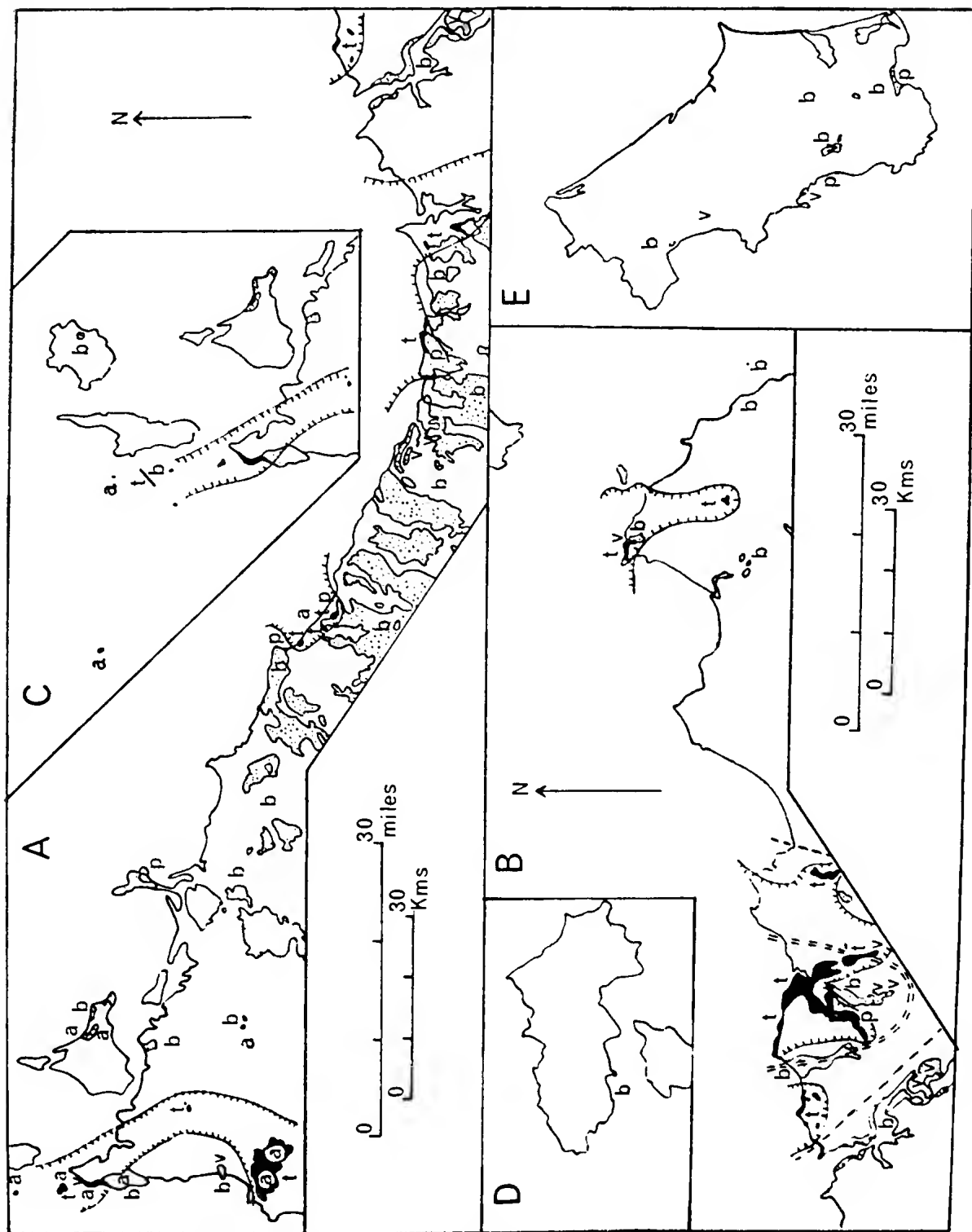


FIG. 3—Map showing distribution of alkali basalt (b) and tholeiitic basalt (t) associations along Bass Strait margins: (A) NW. to N. Tasmania, (B) N. to NE. Tasmania, (C) inset of far NW. coast islands, (D) inset of Cape Barren Island, (E) inset of Flinders Island. The hatched line indicates approximate limits of the tholeiitic association. Known and probable eruptive centres are indicated as lava volcanoes (v), pyroclastic lava volcanoes (p) and aquagene volcanoes (a). The dashed line represents approximate limits of a probable underlying mantle high, with the double dashed lines representing the most pronounced part of the high (data from D. E. Leaman). Note the concentration of volcanism, particularly considerable tholeiitic volcanism, over this feature.

the spectacular promontories of coarse alkali basalt with differentiated phases (The Nut, Table Cape) have been considered large necks, but recent work suggests that they are probably deeply ponded lavas up to 135 m thick, resembling the coarse flows in the Tamar Valley (Sutherland, 1969b, 1971a; Cromer, 1972; unpublished observations).

A broad maximum of Tasmanian volcanic activity during Oligocene-Miocene times contrasts with the pattern found on the opposing Victorian margin (Sutherland, 1969a). It falls within a major phase of sea-floor spreading between Australia and Antarctica (Griffiths & Varné, 1972; Sutherland, Green and Wyatt, 1972) and more locally corresponds with two periods of relatively abrupt tectonic adjustment in the Bass Basin in late Oligocene and mid-Miocene times (Richards & Hopkins, 1969). Both alkali basaltic and tholeiitic lavas were generated, with tholeiitic eruptions concentrated in a mid-Cainozoic peak of activity (Figs. 2 & 3). The tholeiitic centres around Noland Bay appear to lie over a broad mantle high that increases in gradient towards Bass Strait (based on gravity data; D. E. Leaman, pers. comm.). This favours a higher level generation for the tholeiitic lavas than for the alkali basalts, while their tendency towards a concentration along the north coast suggests that some mantle upwarping may be a feature of the southern margin of the Bass Basin. Thus, the relative extent to which blocking action of earlier volcanism or later uplift and warping has determined the present distribution of the Miocene marine sedimentation on the Tasmanian margin needs further evaluation.

Quaternary Deposition and Erosion.

The Tasmanian side of Bass Strait appears to have remained relatively passive without any significant tectonism and volcanism since latest Tertiary times, in contrast to the Gippsland-Otway axis on the north side (Sutherland, 1971b; Sutherland, Green & Wyatt, 1972). There is little current seismic activity, but a westerly striking seismic zone extends across Flinders Island and Bass Strait from Long. 156° to 144° (Doyle, Everingham & Sutton, 1968). The coastal history has been mainly one of glacio-eustatic fluctuations combined with periods of extensive dune building in favourable situations.

The oldest known Pleistocene or latest Tertiary cool marine transgression occurs on the east coast of Flinders Island (Memana Formation, probably Werrikoian age; Sutherland & Kershaw, 1971) and has yet to be identified on inner Bass Strait shores. Levels associated with marine and littoral

deposits have been measured at heights above present sealevel of about 37-45 m (King Island), 30-33 m (Sisters Creek, Ulverstone, Tamar, Bridport, Flinders Island), 20-23 m (King Island, Duck Bay, Rocky Cape, Ulverstone, Tamar, Flinders Island), 12-15 m (Rocky Cape, Ulverstone, Tamar) and 6-9 m (King Island, Rocky Cape, Bridport, Cape Portland): (Gill & Banks, 1956; Jennings, J., 1959b, 1961; Jones, 1965; Marshall et al., 1969; Jennings, D. & Sutherland, 1969; Chick, 1971, Sutherland & Kershaw, 1971; Kershaw & Sutherland, 1972). The levels between 6-23 m are usually assigned to the Last Interglacial seas and the higher levels to older interglacial seas. Deltaic and coastal palustrine deposits of Last Interglacial age are also known at City of Melbourne Bay, King Island and at Mowbray Swamp (37,500 + years; Gill & Banks, 1956; Jennings, J., 1959b; Dury, 1964).

Dune building dates back to the early Pleistocene or older and some consolidated dune limestones on Flinders Island contain derived Upper Miocene foraminiferal faunas (Sutherland & Kershaw, 1971). Regionally dune series tend to be calcareous on westerly and northerly facing shores, and siliceous on easterly and southerly facing shores, particularly on the larger Bass Strait Islands; possible reasons for such a distribution are discussed by Jennings, J., (1968) and Kershaw & Sutherland (1972). Parabolic orientations of dunes are generally consistent with wind directions similar to those of the present regimes and lagoons are commonly associated with the coastal dunes.

Marine regressions associated with glacial periods extended dune building and drainage outlets well beyond and below the present coasts (Edwards, 1941; Jennings, J., 1959a). The lowering in sea-level was apparently sufficient to link Victoria with Flinders Island (-46 m) and Tasmania (-64 m; Jennings, J., 1959a; Gill, 1971), allowing migrations and subsequent isolation of faunas during periods of interglacial high seas. Faunas extant on the north Tasmanian coasts during the Last Interglacial included those with giant and other now extinct marsupials found at King Island, Mowbray Swamp (37,760 years) and Scotchtown Cave (Gill & Banks, 1956; Jennings, J., 1959b; Hopc, 1969).

Pebble and cobble deposits on beaches and in raised storm ridges are a feature of the coast around the mouths of the Forth and Mersey Rivers (Davies, 1959; Chick, 1971). They are considered to represent material washed down these rivers by glacial meltwaters associated with the Last Glacial and partly redistributed by later marine action. Probable Pleistocene fluvio-glacial deposits with a very high proportion of very large boulders are

known in close proximity to the coast in the Forth Valley at Palooa (Burns, 1964).

The post-Glacial sea rise (18,000 to 6,000 years ago) isolated Tasmania between 15,000 to 11,000 years ago, finally drowning the coast to its present level, where 'drowned forests' are known at Badger Head Bay ($7,380 \pm 100$ y. BP), Port Sorell and on Cape Barron Island (Jones, 1968; Gill, 1971). Beach ridge and fore dune systems, related to post-Glacial seas, line the present sandy coasts and have been studied at King Island, Black River, Ulverstone, Port Sorell, Greens Beach and Flinders Island (Gill & Banks, 1956; Jennings, J., 1959b; Davies, 1961; Chick, 1971; Kershaw & Sutherland, 1972). The ridge systems associate with and date from old shore lines between 1-3 m above present level and are considered to be mid-Holocene in age. Whether this level represents a higher sea, as has been suggested for similar levels on the Victorian coast (Jenkin, 1968; Gill, 1971), or results from local variations is at present a matter of debate (Chick, 1971; Kershaw & Sutherland, 1972; Gill & Hopley, 1972).

The isolation of Tasmania and the biogeographic effect on the mammal faunas of Bass Strait has been discussed by Hope (1969). Species now extinct in local populations have been recorded from sub-fossil remains found in cave deposits (dated 8,100-8,200 years in the Ranga Cave, Flinders Island) and sand blows (Hope, 1969; Sutherland & Kershaw, 1971). The Tasmanian Aborigine, similarly cut-off from his mainland origins has left his record on the present Bass Strait shores in midden sites and stone quarries, which date back to at least, $8,120 \pm 165$ y. BP at Rocky Cape Cave (Jones, 1968; Jennings, J., 1971; Sutherland, 1972a).

Extraneous, natural visitations in the Bass Strait record include sporadic arrivals of meteoric showers (Flinders Island tektite, Sutherland & Kershaw, 1971; Lefroy iron and Moorleah stone, Hodge-Smith & Chalmers, 1942) and occasional influxes of large pumice drifts (1962 South Sandwich Eruption, Sutherland, 1965).

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THE DISTRIBUTION AND ZONATION OF INTERTIDAL ORGANISMS IN BASS STRAIT

By ROBERT J. KING*

INTRODUCTION

General accounts of the intertidal ecology of the Victorian and Tasmanian rocky coasts exist, (Bennett and Pope 1953, 1960), but the Bass Strait islands have been largely ignored. The only papers on the intertidal biota of Bass Strait islands which give more than species lists are those of Guiler et al. (1958) and Gillham (1965) on the intertidal ecology of Fisher Is., Saenger (1967) on the littoral plants of Flinders Is., and the brief mention of some Bass Strait islands in Bennett and Pope (1960).

The aim of the present work is to provide a detailed descriptive account of some aspects of the intertidal ecology of the Bass Strait islands, and to summarize the existing data on environmental conditions.

The data are assembled as descriptions of the intertidal zonation, and the sublittoral zones receive scant attention. The terminology adopted is that of Lewis (1961) and zones are established on biological criteria only. No attempt is made to correlate zones of organisms with tidal levels.

In this account the major emphasis is on ecologically important species and particularly those which are part of the zonation pattern. A representative collection of intertidal barnacles and molluscs has been lodged in the National Museum of Victoria. Algae are incorporated in the herbarium of the Melbourne University Botany School (MELU).

ENVIRONMENTAL CONDITIONS.

WAVES

The objective measurement of wave action is seemingly impossible. Attempts have been made to place the measurement of turbulent water motion on a quantitative basis (Lewis, 1968) but such methods are of little use in broad scale ecological surveys where localities may be visited only once or twice and even then only under favourable weather conditions. It is also probable that maximum, and possibly even minimum, conditions of wave action will override general conditions.

In an attempt to clarify terms used in their work on Tasmanian shores, Bennett and Pope (1960: 221) proposed a set of descriptions of degree of 'exposure' and I have used their terms. Where field trips to a locality have been of short duration, assessment is made on personal observations. The presence and absence of some species has also influenced my assessment although I am well aware of the logical inconsistency involved in such an approach i.e. that the species occur on a shore because of the degree of wave action, and that the shore must be subjected to a certain degree of wave action because it has these species. Before a species can be used as a reliable indicator organism for wave action it must be shown that the species is responding only to that factor. The presence of *Cellana solida* (Blainville) is usually indicative of local shelter on coasts of maximal and sub-maximal wave action. Observations on Curtis Is. indicate that the limiting factor is not the degree of wave action in open positions but is perhaps the distribution of barnacles which is in turn dependent on substrate.

Rough seas are common in W. Bass Strait as winds from the W. and SW. have a long fetch over open ocean. Cape Bridgewater, W. Victoria, is accepted as a standard maximum for wave action (Bennett and Pope, 1953). Wave conditions on the W. coast of King Island are maximal but less severe than on the W. Victorian coast. The northern coast of Tasmania is sheltered from oceanic conditions and is classified as sheltered open coast. The E. Bass Strait islands range up to the submaximal wave action category although where the coast plunges steeply into deep water, e.g. Curtis Is., maximal wave action is encountered.

TIDES

Tides in Bass Strait are mostly semidiurnal in nature with a marked diurnal inequality while tides along the north coast of Tasmania are semidiurnal. Tidal range varies from approximately 1 m in W. Bass Strait to approx. 2.5 m in the E. Bass Strait islands. This maximum range of tide

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corresponds to the region where there is the greatest reduction in both the depth and width of Bass Strait.

CURRENTS

Studies on current systems in SE. Australia have concentrated largely on the E. Australian seaboard and in the W. Bass Strait area. Currents have a marked influence on temperature distribution but can also be important in the distribution of planktonic larval forms. CSIRO studies in W. Bass Strait have been concerned with the distribution of crayfish larvae (Vaux & Olsen, 1961).

Bass Strait water is thought to come from three main sources (Newell, 1961). Using the terminology proposed by Rochford (1957) these are: (i) 'East Australian Current' waters—subtropical waters of high chlorinity and temperature originating from sources to the N. and E., (ii) Subantarctic waters—cold and low chlorinity waters traced to the circumpolar west wind drift, (iii) high chlorinity N. Bass Strait waters thought to be derived from the Spencer and St. Vincent Gulf area. Wyrtki (1960) shows the main features of surface water movements in the E. Australian region including Victoria and Tasmania. The essential feature is the general flow W. to E. in the southern portion. The pattern develops in response to the westerly winds and the obstruction caused by the Tasmanian land barrier. Along the E. Australian seaboard there is a general N. to S. flow, the 'East Australian Current'. The structure of the current is outlined in Hamon (1961, 1965), and Boland and Hamon (1970). Highley (1967) re-

views ocean circulation off the E. coast of Australia.

Newell (1961) suggests that the effect of warm E. coast waters is felt in Tasmania as far south as 40°S. Hamon (1961, 1965) shows that the 'East Australian Current' turns away from the coast at approximate latitude 33°-34°S but in autumn under the influence of strong NE. winds may extend as far as Eden, 37°S. Highley (1967) suggests that eddy systems breaking off from the 'East Australian Current' are responsible for the transport of warmer E. coast water as far south as Tasmania. It is likely that this influence of warmer water could extend to the E. Bass Strait islands although the temperature distribution maps of Newell (1961) do not show this. CSIRO data for the period Jan.-April 1971 (*Aust. Fish.* 31 (7) July 1972: 31) show the influence of the East Australian Current extending across Bass Strait during an atypical season.

Vaux and Olsen (1961) and Newell (1961) show the drift of surface waters in W. Bass Strait in the basis of drift bottle recoveries, Fig. 1.

There appears to be a reasonable correlation between these results and the wind pattern for the W. Bass Strait region. The presence of a north flowing surface current along the W. coast of Tasmania is not shown by Wyrtki (1960) except for March. The presence of such a water movement may be part of the explanation for the occurrence of colder summer waters in the W. Bass Strait region.

Dannevig (1915) postulates an oscillating body of water offshore from the N. Tasmanian coast. He considers that flood tides enter Bass Strait

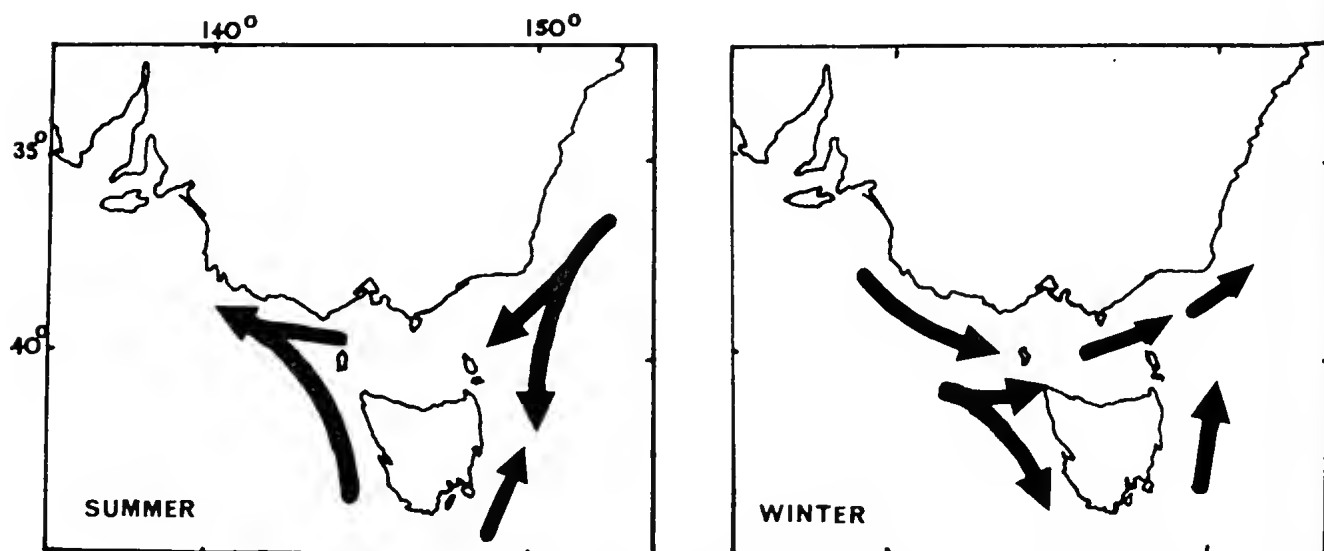


FIG. 1—Movement of surface waters as indicated by drift bottle recoveries (after Vaux and Olsen, 1961).

from both the E. and W., and tide ebbs back through both ends of the Strait. This concept is supported by Pollock (1971). Using predicted tidal data, Pollock constructed co-tidal diagrams for S.E. Australia. These show a variable pattern but the essential feature is the presence of two co-tide lines representing the same time and running N-S. at each end of Bass Strait. Pollock suggests that this is due to wave fronts entering Bass Strait from both the E. and W. These would interfere with each other to form a stationary wave and interchange of water between Bass Strait and the open water would be restricted.

WINDS

Winds throughout Bass Strait are predominantly from the western sector, but in summer there is a strong southerly component in W. Bass Strait. SE. gales affect the eastern portion of the Strait at infrequent intervals particularly in autumn. The predominant wind direction affects height of waves and gives an indication of the direction of rough weather but frequently local topography is an overriding factor.

SEA-WATER TEMPERATURES

Sea-water temperatures along the southern Australian coast are summarized in the charts of the Royal Netherlands Meteorological Institute (1949). More recent data for the Bass Strait region collected by the CSIRO Division of Fisheries and Oceanography, are summarized in a number of publications.

Newell (1961) collates CSIRO data for the period 1938-59 but plots this for summer (November-March) and winter (May-September) and his data are therefore not directly comparable with other data. Since he does not list data for both the warmest and coldest month this information

cannot be used to classify the area in terms of temperature regimes.

Hynd and Robins (1967) summarize CSIRO data for the years 1957-62 inclusive (except 1959) for SE. South Australia, W. Victoria and Tasmania.

Vaux (1970) presents all CSIRO data for the period 1961-65. These show clearly the concentration of temperature records in areas which are of importance to the commercial fishing industry.

The temperature data for Bass Strait show a summer range of 16-19°C and a winter range of 11-13°C. Sea temperatures in E. Bass Strait are influenced by the 'East Australia Current' and are generally 2-3°C higher than those in W. Bass Strait. Temperature data from Vaux (1970) suggests that the influence of the 'East Australia Current' is variable depending on the extent of its southern movement in different years.

The Dutch charts show the presence of cooler waters during summer in SE. South Australia and W. Victoria. Hynd and Robins (1967) provide evidence of a cold water upwelling for the area Kingston, South Australia to Portland, Victoria. Their temperature graphs show that the range of summer temperatures is wide and that the lowest summer temperature is about the same as the lowest winter temperature. Lower summer temperatures appear to be a permanent feature of this area of coast and temperatures are often 1°C or more lower than those of Bass Strait waters. Besides this upwelling of colder waters there is evidence to suggest summer surface water drift from colder waters off W. Tasmania.

Knox (1963) outlines a classification of coastal waters which is applicable to Australia. Using his terminology the waters of Bass Strait would be regarded as cold temperate mixed waters although E. Bass Strait may in some years range into the transitional warm temperate category.

TABLE 1
Air temperature and relative humidity at stations around Bass Strait.
(Australia, Bureau of Meteorology, 1956)

| Locality | Average daily maximum temp. | | Average daily minimum temp. | | Average rel. humidity 1500 hrs. | |
|--------------------|-----------------------------|------|-----------------------------|------|---------------------------------|------|
| | Jan. | July | Jan. | July | Jan. | July |
| Warrnambool | 21.1 | 13.1 | 12.6 | 6.4 | 69 | 77 |
| Cape Otway | 19.9 | 12.6 | 13.1 | 7.8 | 69 | 75 |
| Wilsons Promontory | 19.3 | 12.2 | 13.8 | 8.7 | 77 | 82 |
| Eddystone Point | 20.4 | 12.8 | 12.7 | 6.8 | 64 | 77 |
| Stanley | 20.0 | 11.9 | 12.1 | 6.5 | 64 | 77 |
| Currie, King Is. | 19.8 | 12.8 | 12.0 | 7.7 | 69 | 85 |

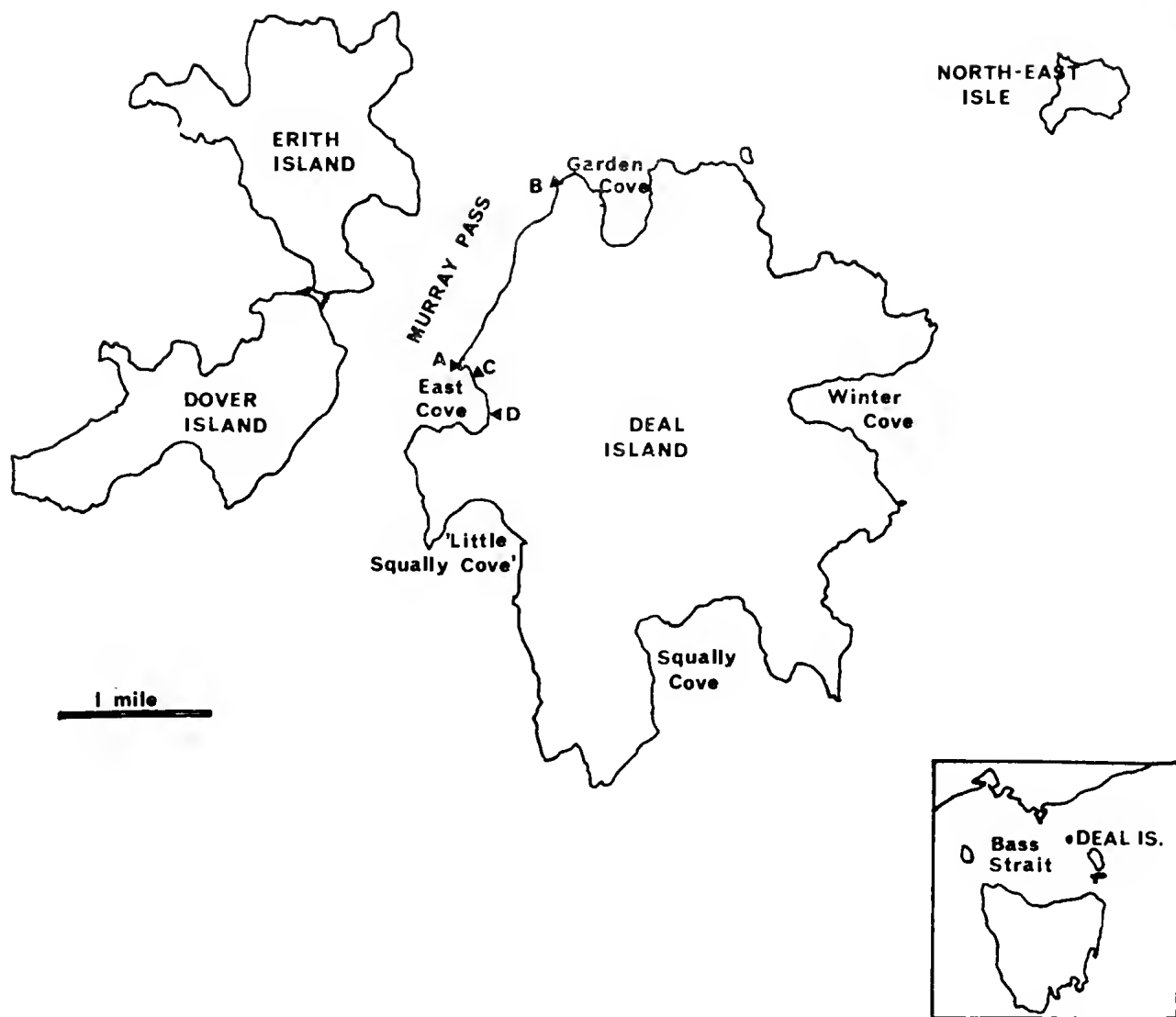


FIG. 2—Map of the Kent Group showing localities and collecting sites mentioned in the text.

AIR TEMPERATURES AND RELATIVE HUMIDITY

No data are available which are directly relevant to the intertidal biota even for mainland coasts. Table 1 lists values for coastal localities around Bass Strait. As with wave action it may be extreme and freak conditions of temperature and relative humidity which are important in limiting species distributions.

EASTERN BASS STRAIT REGION: CURTIS AND DEAL ISLANDS

INTRODUCTION AND LOCATION

Curtis Is. (Lat. $39^{\circ}28'$, Long. $146^{\circ}39'$) is a steeply sloping island approximately 2 km long in

a NNE. direction and about 1 km across. Field work was undertaken during the period 8.ii.71-15.ii.71.

Deal Is. (Lat. $39^{\circ}29'$, Long. $147^{\circ}19'$) is part of the Kent Group, Fig. 2.

Deal Is. is the largest of the Group and is approximately 6 km N.-S., 4 km E.-W. and 287 m at its highest point. Erith and Dover islands are separated from Deal Is. by Murray Pass which is approximately 2.5 km wide and 50-60 m deep. Prevailing weather conditions are from the W. and due to its irregular shape Deal Is. provides a wide range of habitat with regard to wave conditions.

Field work was undertaken during the following periods: 1.ix.68, 21.xi.69 to 25.xi.69 and 2.xii.69.

COASTAL GEOLOGY AND TOPOGRAPHY

The islands of E. Bass Strait form part of the huge granite batholith which extends from Wilsons Promontory (Victoria) to Eddystone Point (NE. Tasmania). On the two islands selected for detailed study (Curtis Is. and Deal Is.) the granite is typically coarse grained. Coastal formations range from steep plunging cliffs to broken rock and isolated boulders with a broad intertidal zone. Dune limestone occurs as a veneer on parts of Deal Is. particularly in the valleys, but it does not outcrop in the intertidal zone. As with other Bass Strait islands the slopes on the northern end are easier and sandy beaches occur at the head of the sheltered bays, East Cove and Garden Cove, on Deal Is.

DEGREE OF WAVE ACTION

Conditions of maximum wave action are encountered on Curtis Is. On Deal Is. 'Little Squally' Cove is open to weather from the S. and W. and represents the roughest water locality investigated. It is regarded as being submaximal-moderate wave action coast while the outer parts of both East and Garden Coves are moderate wave action coasts. Considerable local shelter is provided in the inner portion of these coves.

HISTORY OF ALGAL COLLECTING

In December 1803 Robert Brown was a passenger on the colonial brig the *Lady Nelson* en route to Port Dalrymple, Tasmania, when it was detained in the Kent Group because of bad weather. While there Brown took the opportunity to engage in botanical collecting (Giblin, 1930). It is apparent that he revisited the Kent Group during early 1804 and in the appendix to Flinder's 'Voyage to Terra Australis' Vol. 2, 1814, Brown states that he '... repeatedly landed on Kent's Islands, in Bass Strait, on the shores of which the principal part of Submarine Algae contained in our collections were found' (Stearn, 1960). Brown collected relatively few algae in Australia, about 31 in all, and almost half were specimens from the Kent Group (Womersley, 1959). Most of Brown's specimens have only vague locations and are useless for determination of type localities (Burbidge, 1955); this is not so for his Kent Group specimens, and these islands are the type locality for a number of algae, including *Caulerpa brownii* (C. Agardh) Endlicher, *C. simpliciuscula* (Turner) C. Agardh and *Polyopes constrictus* (Turner) J. Agardh. In the report of the Victorian Field Naturalists' expedition to the Kent Group (Le Souef, 1891) no mention is made of algae although extensive collections were made of Bryozoa. Garreau (1958) in a general article

about the Kent Group refers to the following algae: *Ulva lactuca* Linnaeus, *Hormosira banksii* (Turner) Decaisne and *Phyllospora comosa* (Labillardière) C. Agardh. He states that the bull kelp *Durvillea potatorum* (Labillardière) Areschoug is common, attaining lengths of 25 ft (approximately 8 m). This appears to be incorrect as no *Durvillea* occurs on the island.¹ His reference probably applies to *Macrocystis angustifolia* Bory.

The only recent documented records of algal collecting in the Kent Group are those from Deal Is. by Bennett and Pope in connection with their survey of Tasmanian shores (Bennett and Pope, 1960).

¹ Species absences should always be regarded with caution but since *Durvillea* is so conspicuous and characteristic it could scarcely have been missed.

ZONATION

(i) Maximal wave action. (Curtis Is.).

The limit of the littoral zone is regarded as the upper limit of *Melarapha unifasciata* (Gray). Above this there is a black band of *Verrucaria* and above this a poorly developed band of the orange lichen *Caloplaca murorum* (Acharius) Th. Fries merges with the land vegetation.

(a) *Littoral Fringe*: This zone extends 2-3 m vertically and is characterized by *Melarapha unifasciata*. *Melarapha* is almost entirely restricted to crevices where it occurs in groups of up to about twenty individuals. These individuals are large, commonly about 1 cm in length. On flatter and smooth rock surfaces the blue-green alga *Calothrix crustacea* Bornet et Flahault forms a dense black slippery mat. *Lichina confinis* (Müller) C. Agardh is present in sheltered positions. The upper limit of the barnacles is quite distinct and only a few isolated *Chthamalus antennatus* Darwin occur in the lower part of the littoral fringe. Both *Melarapha unifasciata* and *Lichina confinis* overlap widely with the upper eulittoral.

(b) *Upper Eulittoral Zone*: The upper eulittoral is marked by the presence of the barnacles *Chthamalus antennatus* and *Chamaesipho columna* (Spengler). *Chthamalus* is restricted to the top of the zone whereas *Chamaesipho* has a broad overlap with *Catophragmus polymerus* Darwin of the mid-eulittoral. The barnacles cover the rock densely with approximately 3200 individuals per m² under rough water conditions. *Chamaesipho* occurs as isolated individuals or small patches and not in broad sheets as it does at Wilsons Promontory. With local shelter barnacles virtually disappear. *Melarapha unifasciata* is common in upper parts of this zone while *M. praetermissa* May occurs in sheltered parts.

Siphonarian limpets are common, particularly

Siphonaria diemenensis Quoy et Gaimard which occurs on open rock down to the mid-eulittoral. *S. tasmanica* (Tenison Woods) characteristically occurs in groups in crevices and on steep faces and *S. funiculata* Reeve is found in crevices and crevice pools. *Notoacmea petterdi* (Tenison Woods) is typical of vertical rock faces and extends into the littoral fringe. A number of animals are restricted to crevices, such as the mussels *Modiolus pulex* (Lamarck) and *Mytilus planulatus* (Lamarck) and the barnacle *Tetraclita purpurascens* (Wood), while others including the limpets *Patellanax peroni* (Blainville), *Patelloida alticostata* (Angas), *P. latistrigata* (Angas), and occasionally small *Dicathais textilosa* (Lamarck) are found in crevices but also occur on open rock faces at lower levels or with shelter. *Cellana solida* is found at this level and lower.

Algae are not as conspicuous as animals at this level. *Bangia fuscopurpurea* (Dillwyn) Lyngbye occurs in the uppermost part of this zone particularly on steep rock faces. *Porphyra columbina* Montagne occurs scattered throughout lower parts and into the mid-eulittoral zone. The *Porphyra* during the study period was poorly developed perhaps due to seasonal growth. Both *Bangia* and *Porphyra* are absent from sheltered positions. *Enteromorpha* is characteristic where there is freshwater seepage.

Where protection is afforded by large inshore boulders *Austrocochlea concamerata* (Wood), *Cellana solida*, *Melanerita melanotragus* (A. E. Smith), the starfish *Patiriella calcar* (Lamarck) and *P. exigua* (Lamarck) are common. *Tetraclita purpurascens* becomes abundant in crevices and the crab *Leptograpsodes octodentatus* (Milne-Edwards) is present.

(c) *Mid-Eulittoral Zone*: In rough water areas this zone is dominated by a dense band of *Catophragmus polymerus* which almost entirely covers the rock. The brown alga *Splachnidium rugosum* (Linnaeus) Greville forms a prominent band in the lower regions (Pl. 10, Upper) except on steep rock faces. The *Splachnidium* plants are small (to 3 cm high and 4 mm wide), and are epizoic on *Catophragmus* as at Wilsons Promontory. Above the *Splachnidium*, and extending to the lower parts of the upper eulittoral, are the following algae; *Nemalion elminthoides* (Vellay) Batters sometimes epiphytic on *Cellana solida*, *Porphyra* and *Rivularia firma* Womersley. *Chaetangium fastigiatum* (Bory) J. Agardh occasionally forms a conspicuous band on flat surfaces but is otherwise scattered; in upper parts of the zone it is severely desiccated. *Patelloida alticostata* is scattered above the *Splachnidium* and *Patelloida latistrigata* is common throughout the

zone (over 1,500 individuals per m²). The red anemone *Actinea tenebrosa* Farquhar is abundant in crevice pools.

In sheltered regions the barnacles and algae are absent and the zone is almost bare with a few *Patelloida alticostata*, *P. latistrigata*, *Siphonaria diemenensis* and *S. tasmanica*.

(d) *Lower Eulittoral Zone*: *Balanus nigrescens* Lamarck is the most conspicuous animal at this level and in rough water parts entirely covers the rock. The barnacles are of the tall growth form up to 6 cm high. Older specimens commonly have 10 (-30) smaller individuals epizoic so that a thick crust of barnacles is built up on the rock surface.

The *Balanus* is heavily covered with epiphytic *Corallina officinalis* Linnaeus, *Dasyopsis clavigera* Womersley, *Polysiphonia*¹, and *Sphacella ferruginea* (Harvey) Womersley. *Asparagopsis armata* Harvey is restricted to regions where there is regular wave wash. Encrusting lithothamnia entirely cover the *Balanus*. On flat pockets low in this zone *Xiphophora chondrophylla* (R. Brown ex Turner) Montagne ex Harvey, completely replaces the *Balanus*. Molluscs are uncommon at this level with *Patellanax peroni* and *Poneroplax albida* (Blainville) (up to 71 mm in length) on open surfaces and *Dicathais textilosa* in crevices. The tetrasporic stage of *Asparagopsis*, *Falkenbergia rufolanosa* (Harvey) Schmitz is commonly epizoic on *Poneroplax*.

In sheltered areas *Balanus* is replaced by a coralline algal zone with lithothamnia covering the rock. *Patellanax peroni* is the only animal recorded.

¹ This species is the same as recorded by Womersley (1950 p. 184) as *P. dasyoides* Zan. Womersley (pers. comm.) states it is, however, not Zanardini's species but an undescribed one.

(e) *Upper Sublittoral Zone*: There is no fringing zone of organisms referable to a sublittoral fringe, and the demarcation of the sublittoral is taken as the upper limit of the large brown algae. The nature of the coastline prevents close examination of this area. In roughest water places the dominant alga in the visible sublittoral is *Phyllospora comosa*. *Cystophora moniliformis* (Esper.) Womersley et Nizamuddin also occurs and comparatively rarely *Macrocystis angustifolia* and *Ecklonia radiata* (C. Agardh) J. Agardh. Where *Phyllospora* is in the 'suck back' region, plants are stunted and possess few laterals. In calmer water places *Gelidium glandulaefolium* Hooker et Harvey is subdominant and occurs in dense patches. Occasionally *Balanus nigrescens* with *Dasyopsis clavigera* and *Polysiphonia* extend into this zone.

In most sheltered positions *Perithalia caudata* (Labillardière) Womersley becomes dominant with

epiphytic *Perithamnion dispar* (Harvey) Wollaston. Other species include *Asparagopsis armata*, *Ballia callitricha* (C. Agardh) Kuetzing, *Laurencia elata* (C. Agardh) Harvey, *Plocaminum angustum* (J. Agardh) Hooker et Harvey and *Pterocladia capillacea* (Gmelin) Bornet et Thuret. *Dicathais textilosa* may be abundant under these conditions.

(f) *Pool Flora*: Pools in the mid and lower eulittoral are generally small and shallow, with lithothamnium covering the rock surfaces and no other conspicuous plant life. Occasionally well sheltered pools are formed under boulders. Species found in such pools include *Chaetomorpha aerea* (Dillwyn) Kuetzing, *Chaetomorpha darwinii* (Hooker) Kuetzing, *Cladophora feredayi* Harvey, *Bryopsis gemellipara* J. Agardh, *Ulva lactuca*, *Dictyota dichotoma* (Hudson) Lamouroux, *Amphiroa ephedraea* (Lamouroux) Areschoug, *Ballia callitricha*, *Centroceras clavulatum* (C. Agardh) Montagne, *Ceramium*, *Champia compressa* Harvey, *Cheilosporum sagittatum* (Lamouroux) Areschoug, *Plutymophora amansioides* (Sonder) Womersley, *Polyporolithon patena* (Hooker et Harvey) L. R. Mason, *Polysiphonia* and *Pterocladia capillacea*. In lower pools the brown algae become dominant: *Cystophora moniliformis* (with epiphytic *Corynophloea cystophorae* (J. Agardh), *Ecklonia radiata*, *Macrocystis angustifolia*, *Phyllospora comosa* and *Xiphophora chondrophylla* (with epiphytic *Porphyrellia australis* (J. Agardh) Silva).

(ii) Submaximal-moderate wave action, ('Little Squally' Cove, Deal Is.)

At the head of the cove the intertidal area is a boulder beach strewn with jetsam. South of this area the coastline is of broken granite masses below almost vertical cliffs up to 250 m. The orange lichen *Caloplaca murorum* occurs on the cliff face and the sparse vegetation at this level is mainly *Stipa teretifolia* Steudel, *Carpobrotus rossii* (Haworth) Schwantes, *Disphyma australe* (Solander) J. M. Black and *Calocephalus brownii* (Cassini) F. Mueller.

(a) *Littoral Fringe*: A prominent band of *Verrucaria* marks the littoral fringe. *Melarapha unifasciata* occurs in the lower part of the zone and occupies a vertical range of approximately 3m. *M. praetermissa* occurs at this level but extends into the upper eulittoral zone. *Melanerita melanotragus* and *Lichina confinis* are restricted to areas protected from direct wave action both in the littoral fringe and the upper eulittoral zone. The crab, *Leptograpsus variegatus* (Fabricius) is common amongst boulders.

(b) *Upper Eulittoral Zone*: This zone is relatively bare and is marked by the barnacle

Chthamalus antennatus, and the honeycomb barnacle *Chamaesipho columna* which extends into the mid-eulittoral zone. *Melarapha praetermissa* occurs particularly in crevices. *Enteromorpha* is typical of positions where freshwater seepage occurs.

(c) *Mid-Eulittoral Zone*: The surf barnacle, *Catophragnus polymerus*, is characteristic of the zone. *Cellana solida* is best developed in this zone although it occurs both above and below this level. *Modiolus pulex*, *Patelloida latistrigata* and *Siphonaria diemenensis* occur at this level but the *Modiolus* is restricted to crevices. Occasionally *Rivularia firma* and *Porphyra columbina* are found in the upper part of the zone. *Splachnidium rugosum* forms a conspicuous band with the uppermost individuals dying off. Price (1966) makes a similar observation at Leonards Bay, Wilsons Promontory where young *Splachnidium* plants develop throughout the *Catophragnus* belt but as the summer approaches the *Splachnidium* band becomes narrower.

(d) *Lower Eulittoral Zone*: This zone is relatively bare on steep faces with stunted corallines and *Ulva lactuca* in the crevices. *Asparagopsis armata* and *Poneroplax costata* (Blainville) are common although *Poneroplax costata* is not recorded east of Wilsons Promontory on the mainland coast.

Where boulders and broken rock shelter this zone from wave action *Hormosira banksii* and *Gelidium pusillum* (Stackhouse) Le Jolis are common. *Cellana solida* occurs, often with epizoic *Scytosiphon lomentaria* (Lyngbye) Link. *Cominella lineolata* (Lamarck) is recorded from this zone. Pools at this level have a flora similar to that recorded in sheltered parts of the upper sublittoral zone.

(e) *Upper Sub-Littoral Zone*: *Phyllospora comosa* is the dominant alga visible in the sublittoral zone but in sheltered parts there is a clearly defined band, 10-15 cm vertical range, of *Xiphophora chondrophylla* above the *Phyllospora*. This *Xiphophora* band is emergent for several hours during periods of low water spring tides and is a common feature of zonation on the island, (Pl. 10, Lower). It is interpreted as sub-littoral for two main reasons:

The species which occur as sub-dominants in this zone are primarily subtidal and although the upper limit is clearly defined some individuals of *Xiphophora* do extend well below the fringing band. The species associated with *Xiphophora* are *Cystophora moniliformis*, *Leathesia difformis* (Linnaeus) Areschoug, *Sargassum* species, *Coralina officinalis*, *Haliptylon subulata* (Ellis et Solander) Johansen and small *Laurencia* species.

Where both *Xiphophora* and *Cystophora*

torulosa (R. Brown ex Turner) J. Agardh occur together at Deal Is. the *Xiphophora* band lies below the *Cystophora torulosa*. In Victoria and Tasmania *C. torulosa* forms a distinct lower sub-zone of the lower eulittoral zone. The occurrence of a dense band of *Xiphophora chondrophylla* at this level is not a common feature of E. Bass Strait islands although it is characteristic of sheltered open coast on King Is. *Xiphophora gladiata* (Labillardière) Montagne ex Kjellman occupies a similar position on sheltered and semi-sheltered Tasmanian mainland shores.

The subtidal rock surfaces are entirely covered with encrusting lithothamnia. Species commonly associated with *Phyllospora comosa* include *Ballia callitricha*, *Gelidium australe* J. Agardh, *Laurencia elata*, *L. filiformis* (C. Agardh) Montagne and *Plocamium angustum*. Other species recorded in this zone include *Bryopsis plumosa* (Hudson) C. Agardh, *Dictyota dichotoma*, *Halopteris pseudo-*

spicata Sauvageau, *Perithalia caudata* and *Phacelocarpus labillardieri* (Turner) J. Agardh.

The outer parts of both East Cove and Garden Cove, sites A and B, Fig. 2, are classified as areas of moderate wave action. The zonation pattern is similar in most respects to that at 'Little Squally' Cove. The main differences are:

The presence of *Balanus nigrescens* in the lower eulittoral zone;

Actinea tenebrosa and *Tetracrita purpurascens* are present but confined to crevices; and

At site A where the granite cliffs fall almost vertically into the sub-littoral the only algae visible in the upper sub-littoral zone are *Macrocystis angustifolia* and *Phyllospora comosa*.

(iii) Moderate-sheltered open coast. (East Cove and Garden Cove, Deal Is.)

East Cove and Garden Cove both provide a range of environment from moderate wave action,

TABLE 2
Distribution of important zone forming organisms in East Cove, Deal Is., E. Bass Strait.

| Degree of wave action | Moderate with strong tidal scour. | Sheltered open coast | Extreme sheltered open coast |
|-------------------------|--|---|--|
| Locality | East Cove, site A | East Cove, site C | East Cove, site D |
| Nature of substrate | Steep sloping granite | Gently sloping granite (30° - 70°) | Broken granite and boulders with sand in the sub-littoral zone. |
| Littoral fringe | <u>Verrucaria</u> <u>Melarapha unifasciata</u> <u>M. praetermissa</u> | <u>Melarapha unifasciata</u> <u>M. praetermissa</u> | <u>Melarapha unifasciata</u> |
| Upper eulittoral zone | <u>Cellana solida</u> <u>Chamaesipho columna</u> <u>Chthamalus antennatus</u> <u>Patelloida latistrigata</u> <u>Siphonaria diemenensis</u> <u>Siphonaria funiculata</u> | <u>Cellana solida</u> <u>Chamaesipho columna</u> <u>Patelloida alticosta</u> <u>Patelloida latistrigata</u> <u>Siphonaria diemenensis</u> | <u>Scytosiphon lomentaria</u> <u>Cellana solida</u> <u>Melanerita melanotragera</u> |
| Mid-eulittoral zone | <u>Porphyra columbina</u> <u>Spilachnidium rugosum</u> <u>Catophragmus polymerus</u> <u>Cellana solida</u> <u>Chamaesipho columna</u> | <u>Porphyra columbina</u> <u>Rivularia firma</u> <u>Cellana solida</u> <u>Chamaesipho columna</u> | <u>Gelidium pusillum</u> <u>Cellana solida</u> <u>Cateolaria caespitosa</u> (occasional) |
| Lower eulittoral zone | <u>Corallina officinalis</u> <u>Balanus nigrescens</u> <u>Poneroplax costata</u> | <u>Corallina officinalis</u> <u>Hormosira banksii</u> <u>Colpomenia sinuosa</u> <u>Cystophora torulosa</u> | <u>Corallina officinalis</u> <u>Hormosira banksii</u> <u>Laurencia botryoides</u> <u>Ulva lactuca</u> <u>Cellana solida</u> <u>Colpomenia sinuosa</u> <u>Cystophora torulosa</u> <u>Leathesia difformis</u> |
| Upper sub-littoral zone | <u>Macrocystis angustifolia</u> <u>Phyllospora comosa</u> encrusting lithothamnia | <u>Xiphophora chondrophylla</u> <u>Caulerpa</u> species <u>Ecklonia radlata</u> & mixed Fucales | <u>Caulerpa brownii</u> <u>Posidinia australis</u> & epiphytes |

e.g. site A, to extreme sheltered open coast, e.g. site D. Table 2 outlines the basic pattern observed in East Cove.

GENERAL OBSERVATIONS ON THE MARINE BIOTA OF EASTERN BASS STRAIT.

(i) Under rougher water conditions the algae associated with the dominant large brown algae of the upper sub-littoral zone are predominantly Rhodophyceae whereas the Phaeophyta and Chlorophyta are better represented in sheltered localities. Species found with *Macrocystis angustifolia* and *Phyllospora comosa* include *Halopteris pseudospicata*, *Amphiroa anceps* (Lamarck) Decaisne, *Gelidium australe*, *Laurencia elata*, *L. filiformis*, *L. heteroclada* Harvey, *Plocanium angustum*, *P. cartilagineum* (Linnaeus) Dixon and *P. costatum* (C. Agardh) Hooker et Harvey. In sheltered positions where *Ecklonia radiata* becomes dominant, (often with *Xiphophora chondrophylla* as a sub-littoral fringe), the number of species visible in the sub-littoral zone is increased. Species present include *Caulerpa brownii*, *C. geminata* Harvey, *C. vesiculifera* Harvey, *Acrocarpia paniculata* (Turner) Areschoug, *Caulocystis cephalornithos* (Labillardière) Areschoug, *Cystophora moniliformis*, *C. subfarinata* (Mertens) J. Agardh, (vesiculate form), *Dictyota dichotoma*, *Pachydietyon paniculatum* (J. Agardh) J. Agardh, *Phyllospora comosa*, *Sargassum* species (infertile), *Corallina officinalis*, *Plocanium angustum*, *P. cartilagineum*, and *Pterocladia capillacea*. *Portphillipia australis* is a common epiphyte on *Xiphophora*.

(ii) Barnacles on open rock are characteristic of rougher water areas. *Balanus nigrescens* and *Catophragmus polymerus* occur only where there is at least moderate wave action while *Chamaesipho columna* and *Chthamalus antennatus* are more tolerant of shelter. *Tetraclita purpurascens* is an exception to this preference for rough water conditions and it is confined to shaded crevices.

(iii) *Cellana solida* is a conspicuous mid-eulittoral organism occurring, as in Tasmania, at the bases of boulders on the inner part of the shore and at lower levels in sheltered sites. On Curtis Is. *C. solida* also occurs occasionally on open rock faces where it is subjected to extreme wave action. Individuals from the inner shore are generally smaller, 40 (28-50) mm in length (32 measurements), than those from outer positions, 53 (41-84) mm in length (21 measurements).

The difference between sizes on sheltered and open rock may be due to a number of factors, such as the relative ease of physical removal of small individuals from open rock face by direct wave action or by predation from oyster catchers.

Under rough water conditions *Cellana* appears to be favoured where there are aplite intrusions in the granite. On the smooth aplite barnacle numbers are reduced (Table 3).

It is therefore possible that the preference for inshore positions generally shown by *Cellana* may be due to competition from organisms such as barnacles which are favoured on rough water outer parts. Guiler et al. (1958) have made a similar suggestion to account in part for the absence of *C. solida* from south point on Fisher Is.

(iv) Where *Patelloida latistrigata* and *P. alticostata* occur at the same site the latter appears to favour sheltered positions.

(v) *Melanerita melanotragus* is not a reliable zonal indicator as it has a marked tidal periodicity in its activity (Guiler et al., 1958). It is however, an indicator of sheltered positions on open coast.

(vi) *Hormosira banksii* and *Cystophora torulosa* are two reliable zonal indicators for the lower eulittoral zone in sheltered localities. Both are less common in rough water areas where they are restricted to crevices. Algae such as *Splachnidium rugosum* and *Porphyra columbina* occur only in rough water positions.

(vii) *Galeolaria caespitosa* Lamarck occurs only in sheltered positions. *Actinea tenebrosa* is common at all levels in such places but with increase in wave action is confined to crevices and crevice pools in the upper and mid-eulittoral zones.

(viii) Under moderate wave conditions the species composition of the lower eulittoral zone is dependent on the slope of the rock surface. On gently sloping faces algae are dominant and include *Asparagopsis armata*, *Ceramium*, *Champia* and young, stunted *Laurencia* species. *Liagora harveyana* is recorded from this zone. On steep rock faces there are fewer algae and the rock is covered with encrusting lithothamnium with *Balanus nigrescens* and *Poneroplax costata* the only conspicuous animals.

(ix) Where the upper sub-littoral zone is sand with occasional rock and is very sheltered *Posidonia australis* Hooker occurs with epiphytic *Myriogloia sciurus* (Harvey) Kuckuck, *Caulerpa brownii* is common on rock, and in Garden Cove

TABLE 3
Density of Barnacles and *Cellana solida*
(number of individuals per 25 cm²) on granite and
aplite, mid-eulittoral zone.

| | <i>Catophragmus polymerus</i> | <i>Chamaesipho columna</i> | <i>Cellana solida</i> |
|---------|-------------------------------|----------------------------|-----------------------|
| Aplite | 75 | 47 | 20 |
| Granite | 150 | 120 | 0 ⁻³ |

Dictyopteris acrostrichoides (J. Agardh) Boergesen is also found.

(x) *Bryopsis vestita* J. Agardh is abundant in East Cove, Deal Is., where sand covers the rock in the mid and lower eulittoral zones. It is also found on the jetty piles.

(xi) A *Ralfsia*-like crust occurs in patches on rock surface throughout the mid-eulittoral zone and on the shells of *Cellana solida*. No fertile material appears to be present.

AFFINITIES OF THE EASTERN BASS STRAIT MARINE BIOTA

Plants. Almost all of the species recorded for E. Bass Strait are shared with both the Victorian and Tasmanian floras: only few are shared with either the mainland or Tasmania. *Caulerpa vesiculifera* is present on Deal Is. and on the Victorian coast but is not recorded for Tasmania. Womersley (1956) states that *C. vesiculifera* probably occurs on the N. Tasmanian coast but I have not found it there. *Macrocystis angustifolia* is present on the mainland coast and on Deal Is. and on Flinders Is. (Saenger, 1967). On the Tasmanian east coast the species present is *M. pyrifera* (Linnaeus) C. Agardh. Specimens from Waterhouse Is. and Swan Is. were obtained without holdfasts. Womersley (1954) has established that holdfast characters are the only reliable features to distinguish between *Macrocystis angustifolia* and *M. pyrifera* but the size of the mature lateral blades suggests that the species present in southern Bass Strait is *M. pyrifera*.

A number of species which occur in E. Bass Strait are not found on the New South Wales coast. These include the prominent zone forming cool temperate species *Cystophora torulosa* and *Xiphophora chondrophylla*; also *Ballia callitricha* and the siphonous green algae *Bryopsis vestita*, *Caulerpa brownii* and *C. longifolia* C. Agardh.

Floristically then, the E. Bass Strait islands are linked with Victoria and Tasmania. The limited data available requires that species' absences be regarded with caution. *Durvillea potatorum* is definitely absent and no satisfactory reason has been found to account for this. Sea temperatures in E. Bass Strait are certainly not the limiting factor since *Durvillea* extends to Tathra, New South Wales; substrate and degree of wave action are unlikely to control distribution as *Durvillea* occurs under similar conditions at Wilsons Promontory.

Animals. Most of the prominent zone forming animals of the E. Bass Strait islands are found on both the Victorian and Tasmanian coasts, but a few fail to bridge the Strait. *Balanus nigrescens* is common on Curtis Is. and present on Deal Is. but I have not recorded it further south. Guiler

(1960a) suggests that it may be present on the NE. corner of Tasmania but I have not seen it there nor on Swan Is. or Goose Is. *Cellana solida* is a dominant eulittoral species in E. Tasmania and through the E. Bass Strait islands, and although it has been recorded for Wilsons Promontory (Macpherson and Gabriel, 1962) *C. tramoserica* (Sowerby) is the common species at this locality.

WESTERN BASS STRAIT REGION: KING ISLAND.

INTRODUCTION AND LOCATION

King Is. is approximately 58 km due S. (39° 35'S., 40° 10'S.) and 21 km wide (143° 51'E., 144° 10'E.) and lies to the W. of the Bassian basin (Weeks and Hopkins, 1967). Prevailing weather conditions are from the W., and the N.-S. orientation of the island, coupled with the relatively shallow off-shore water on the eastern coast (Admiralty Map 404, King Is.), ensures a range of environmental conditions from maximal wave action to sheltered open coast.

Localities mentioned are shown in Fig. 3. Field work was undertaken from 28.v.71 to 31.v.71, and this should be kept in mind when comparing observations made here, with summer observations at E. Bass Strait localities.

COASTAL GEOLOGY AND TOPOGRAPHY

Jennings (1959) has made a detailed study of the coastal geomorphology of King Is. Localities on the W. coast and at Naracoopa are on schists and quartzites of presumed pre-Cambrian age. The shore line consists of irregular rocky reefs which project up to 3 m or more above low tide. At Naracoopa the rocky reefs are truncated in upper regions by a sandy beach. Angular, steep sided rock pools are common.

The NE. coast, site 3, consists of low granite cliffs falling abruptly into shallow water. Occasionally the granite slopes gently or forms almost level shelves; pools are not common.

DEGREE OF WAVE ACTION

Conditions on the west coast are almost invariably rough and the least sheltered positions are rated as maximal wave action, site 2. Local conditions have a marked effect; near Currie, site 1, offshore rock mitigates wave action, and the locality is classified as submaximal wave action. Site 3 in the NE. of the island falls within the category of moderate wave action while Naracoopa, site 4, is regarded as sheltered open coast.

These assessments are made on both personal observations and information provided by local inhabitants, although it is obvious that the degree of wave action will vary with changing weather

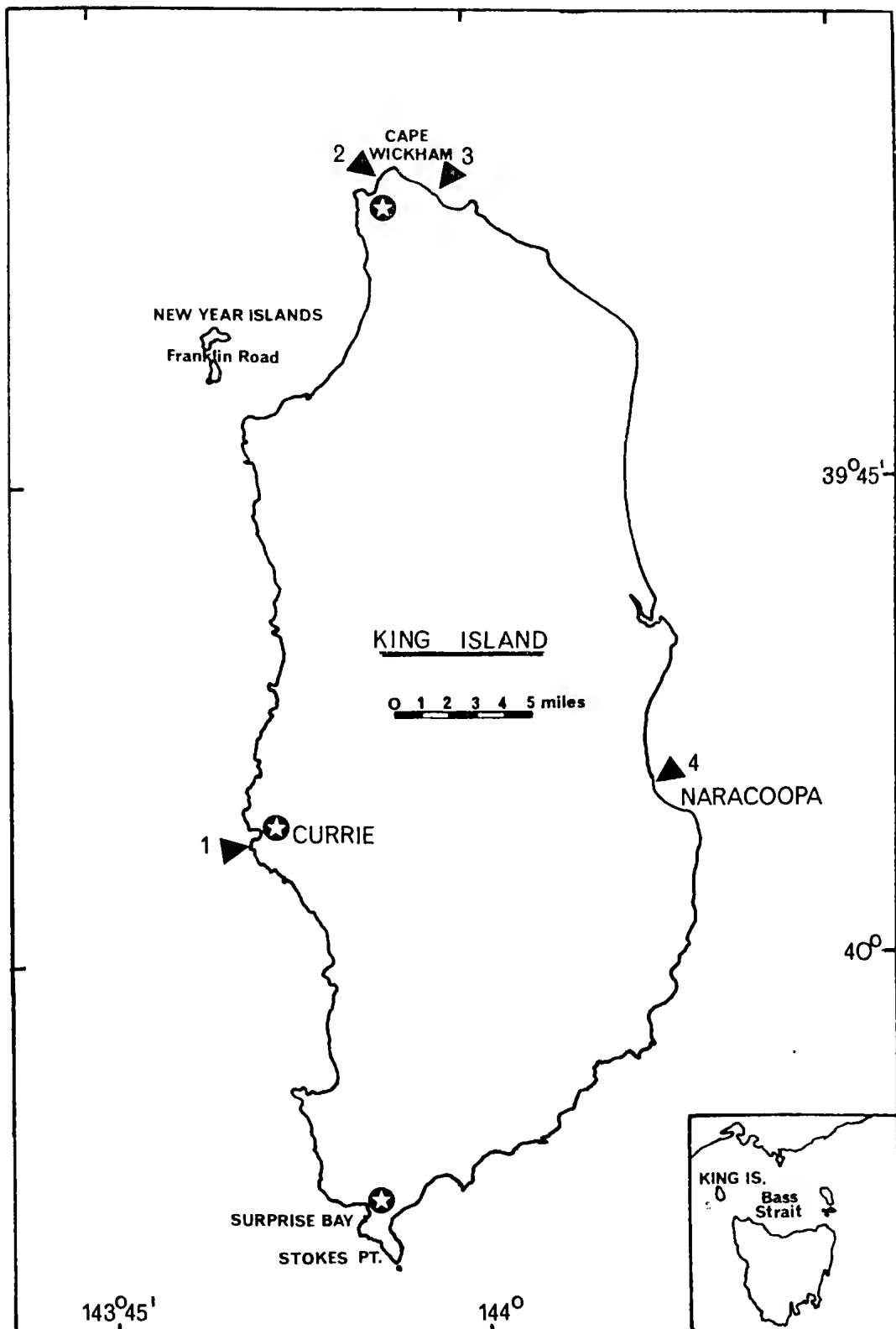


FIG. 3—King Island showing localities and collecting sites mentioned in the text.

conditions. The rough water nature of the western coastline is illustrated by the huge quantities of drift weed, mainly *Durvillea potatorum*, which lies in decomposing heaps up to 1 m high. Campbell (1888) made a similar observation.

HISTORY OF ALGAL COLLECTING

King Is. was discovered in 1798 but it was not until December 1802 that Lieutenant Robbins took formal possession for the British Crown. In April 1802 Robert Brown, on board the *Investigator*, spent several days on the island, but his journal makes no reference to the algae (see Willis and Skewes, 1955, for a transcription of R. Brown's journal).

In the report of the Victorian Field Naturalists' excursion (Campbell, 1888), Baron von Mueller lists all plants recorded from the Island including

those of R. Brown, as well as later collectors. This list includes Lycopophyta and Pterophyta but algae are not included, which again indicates that Brown did not collect algae on King Is.

In December 1802, Baudin in the corvette *Le Géographe* visited the island and Péron, the zoologist of *Le Géographe* made some mention of the algae. 'Tous les rivages étoient couvertes d'une grande quantité de fucus, qui, pour la plupart, formoient des espèces nouvelles; j'en décrivis plusieurs sous les noms de *f. phyllotrichos*, de *f. canlitortus*, de *f. panacrochordus*, etc.: cette dernière paroît composée des petites verrues. Je retrouvai pareillement sur ces bords les fucus curieux que j'avois précédemment décrit sous le nom de *phyllophorus*, et le *f. gigantinus* présentoit aussi çà et là de puissans débris'. (Péron, 1824, vol 3: 21-22). Bennett suggests that *f. pana-*

TABLE 4
Distribution of important zone forming organisms on King Is., W. Bass Strait.

| Degree of wave action | Maximal-submaximal | Moderate | Sheltered open coast |
|-------------------------|---|---|---|
| Region | West coast | North-east coast | East coast |
| Locality | Currie and Cape Wickham (sites 1 & 2) | 1 ml. N.E. of Cape Wickham (site 3) | Naracoopa (site 4) |
| Substrate | Precambrian schists and quartzites | Granite | Precambrian schists and quartzites |
| Littoral fringe | <u>Melarapha paludinella</u> <u>M. praetermissa</u> | <u>Melarapha praetermissa</u> | <u>Lichina confinis</u> <u>Melanerita melanotragus</u> <u>Melarapha praetermissa</u> |
| Upper eulittoral zone | <u>Chamaesipho columna</u> <u>Notoacmea mayi</u> <u>N. petterdi</u> <u>Siphonaria diemenensis</u> <u>S. tasmanica</u> | <u>Lichina confinis</u> <u>Cellana tramoserica</u> <u>Chamaesipho columna</u> <u>Siphonaria diemenensis</u> | <u>Lichina confinis</u> <u>Austrocochlea constricta</u> <u>Bembicium nanum</u> <u>Cellana tramoserica</u> <u>Chamaesipho columna</u> <u>Siphonaria diemenensis</u> <u>Tetraclita purpurascens</u> |
| Mid-eulittoral zone | <u>Rivularia firma</u> <u>Cellana tramoserica</u> <u>Chamaesipho columna</u> ----- <u>Corallina officinalis</u> <u>Pseudolithophyllum hyperellum</u> | <u>Rivularia firma</u> <u>Chamaesipho columna</u> ----- <u>Gelidium pusillum</u> <u>Galeolaria caespitosa</u> | <u>Rivularia firma</u> <u>Cellana tramoserica</u> <u>Chamaesipho columna</u> <u>Galeolaria caespitosa</u> |
| Lower eulittoral zone | <u>Lithothamnion</u> <u>Patellanax peroni</u> <u>Poneroplax</u> species | <u>Hormosira banksii</u> <u>Codium fragile</u> <u>Poneroplax</u> species ----- <u>Cystophora torulosa</u> | <u>Hormosira banksii</u> <u>Laurencia tasmanica</u> <u>Cellana tramoserica</u> <u>Patelloida alticostata</u> ----- <u>Cystophora torulosa</u> |
| Upper Sub-littoral zone | <u>Durvillea potatorum</u> | <u>Caulerpa brownii</u> <u>Cystophora moniliformis</u> <u>C. siliquosa</u> & mixed Fucalae <u>Macrocystis angustifolia</u> | <u>Xiphophora chondrophylla</u> ----- <u>Caulerpa brownii</u> <u>Cystophora moniliformis</u> <u>C. siliquosa</u> & mixed <u>Caulerpa</u> species & Fucalae |

crochordus is *Hormosira banksii*, that *phyllophorus* may well be *Phyllospora comosa* and *f. giganticus* is *Durvillea potatorum* (Micco, 1971: Appendix E).

The only publication on King Is. algae this century appears to be a list of 32 algae collected by Mrs. Spong and identified by A.H.S. Lucas (Ewart, 1907). The McCoy Society for Field Investigation and Research visited King Is. during the 1930's but no report was issued. Algae were collected (Dr. A. Gale, pers. comm.), but no records or specimens have been located.

ZONATION

Zonation is obscured by the dissected nature of the rocky shoreline. The zoning pattern is discussed for the different degrees of wave action and Table 4 summarizes the information for the major zone forming organisms.

(i) Maximal-submaximal wave action, (sites 1 and 2, West Coast).

Maritime zone organisms merge with the littoral fringe where there is no major environmental break at this level. Stokes Point, the southern extreme of the island, is a low spit approximately 7 m high and less than 200 m wide. This area is unprotected and is described as 'only a few feet high and looks like a group of boulders over which the sea is constantly breaking' (Victoria, Public Works Department, 1970). The vegetation on the spit is predominantly *Calocephalus brownii*, *Carpobrotus rossii* and *Disphyma australe*. *Parnelia* and *Caloplaca* occur on rocks across the headland but neither are particularly common. The marine isopod, *Ligia australiensis* (Dana) shelters under loose rock within 7 m of the shore and the crab, *Leptograpsodes octodentatus* is found at distances up to 20 m from high tide mark.

(a) *Littoral Fringe*: *Melarapha praetermissa* is the characteristic organism and occurs at levels up to 5 m above high tide mark, which corresponds to the upper limit of coastal rocks. It is abundant towards the lower limit of the zone and in positions of local shelter. *Melarapha paludinella* (Reeve) occurs on the outer edge and extends into the upper eulittoral zone. *M. unifasciata* is absent. *Notoacmea petterdi* and *N. mayi* May are found on vertical surfaces on the outer edge but *N. mayi* shows a preference for positions with flying spray. *Patelloida alticostata* and *Siphonaria tasmanica* reach this zone but only in crevices or as juveniles. *Lichina confinis* is more common in the upper eulittoral zone but isolated patches occur here. In high level pools on the outer edge *Enteromorpha*, corallines and encrusting lithothamnium are

often found; some shallow pools have dense growth of *Scytosiphon lomentaria* with epiphytic *Giffordia irregularis* (Kuetzing) Le Jolis. These pools undoubtedly receive fresh-water inflow.

(b) *Upper Eulittoral Zone*: The upper limit of this zone is defined by the upper limit of the honeycomb barnacle *Chamaesipho columna*. This barnacle characterizes both the upper and mid-eulittoral zones with a coverage up to 40% and a vertical range of 2 m in open positions. It often, though not invariably, occurs in crevices formed by the differential weathering of the rock. *Tetracelia purpurascens* is the only other barnacle present and is rare and confined to deep sheltered crevices. Only four individuals were found at Cape Wickham in spite of a careful search for this species. *Lichina confinis* occurs in the uppermost part of this zone, particularly on the plates of *Chamaesipho*. *Lepsiella vinosa* Lamarck is found occasionally with the *Chamaesipho*. *Patelloida alticostata* and *P. latistrigata* are mainly confined to crevices while *Siphonaria diemenensis* and more rarely *S. tasmanica* occur on open rock face. *Notoacmea mayi* and *Melarapha paludinella* may become abundant at this level. Small individuals of *Cellana tramoserica*¹ occur throughout the zone except under conditions of extreme wave action.

On inner portions of the reef protected from direct wave action *Bembicium nanum* (Lamarck) and *Melanerita melanotragus* are locally abundant. *Austrocochlea constricta* (Lamarck) is common in shallow pools and *A. concamerata*, which is comparatively rare, is found around pool margins and in crevices.

Pools on the outer edge are characterized by *Chaetomorpha aerea*, *Enteromorpha*, *Colpomenia sinuosa* (Martens ex Roth) Derbès et Solier, occasional *Hormosira banksii* and *Jania fastigiata* Harvey; *Caulerpa obscura* Sonder occurs in dense patches entirely filling some pools. *Actinea tenebrosa* is common in pools and crevices throughout this and the next zone.

¹ The species collected appears to fall within the limits of *Cellana tramoserica*. However *C. solida* (as *C. limbata*) is the species recorded for King Is. in May (1924).

(c) *Mid-Eulittoral Zone*: The mid-eulittoral zone shows a downward extension of some species from upper zones. *Chamaesipho* is still common and *Cellana tramoserica* is more prominent with larger individuals (> 2-3 cm). The lower limit of this zone is marked by a dense band of *Pseudolithophyllum hyperellum* (Foslie) Adey and *Corallina officinalis* in open positions. With slight increase in shelter *Lithothamnium* covered *Galeolaria caespitosa* becomes dominant. Both the *Pseudolithophyllum* and the *Galeolaria* grow so

thickly that they virtually exclude species such as *Cellana* and *Chamaesipho*. *Rivularia firma* occurs in this zone and *Gelidium pusillum* forms a marked band on the *Galeolaria*. *Modiolus pulex* and *Brachidontes rostratus* (Dunker) occur in crevices but neither are abundant. *Kellia australis* (Lamarck) is found in the byssal threads of the *Brachidontes*.

(d) *Lower Eulittoral Zone*: In most positions this zone is neither well developed nor distinct from the immediate sub-littoral zone. Lithothamnium almost entirely cover the rock surface. *Patellanax peroni* is common and at lower levels *Poneroplax costata* and *P. albida* occur. *Hormosira banksii*, with some *Caulerpa brownii* and *Colpomenia sinuosa*, is common where there is local shelter and the rock surface is almost level. Below this there is a narrow but distinct band of *Cystophora torulosa* with occasional young *Zonaria* and *Laurencia* species. *Patiriella exigua* is recorded from this zone and as noted by Dartnall (1971) it is often closely associated with *Hormosira banksii*. *Dicathais textilosa* and *Montfortula rugosa* (Quoy et Gaimard) occur in crevices and also in the upper sub-littoral zone.

(e) *Upper Sub-Littoral Zone*: In positions of maximal wave action *Durvillea potatorum* is characteristically found at this level. Where offshore rocks or *Durvillea* provide shelter the upper sub-littoral zone is dominated by Fucales, in particular *Cystophora moniliformis* and *C. siliquosa* J. Agardh, and corallines. *Caulerpa brownii* is abundant with *C. obscura* on vertical faces and *C. vesiculifera* where waves suck back. Other species occurring under these conditions include: *Apjohnia laetevirens* Harvey, *Caulerpa geminata*, *Chaetomorpha darwinii*, *Dictyosphaeria sericea* Harvey, *Acrocarpia paniculata*, *Cystophora subfarcinata*, *Macrocystis angustifolia*, *Perithalia caudata*, *Phyllospora comosa*, *Sargassum decipiens* (R. Brown in Turner) J. Agardh, *S. heteromorphum* J. Agardh, *Seirococcus axillaris* (R. Brown ex Turner) Greville, *Xiphophora chondrophylla*, *Zonaria turneriana* J. Agardh, abundant young infertile *Zonaria* species, *Corallina officinalis*, *Halipylon subulata*, *Laurencia elata*, lithothamnium, *Metagoniolithon charoides* (Lamouroux) Weber-van Bosse, *Plocamium angustum* and *P. costatum*. With even more shelter *Pterocladia capillacea* occurs and *Polysiphonia nigrita* Sonder is epiphytic on *Cystophora subfarcinata*. Where there is extreme local shelter the following species occur: *Caulerpa brownii*, *Caulocystis cephalornithos*, *Cystophora polycystidea* Areschoug ex J. Agardh, *C. subfarcinata*, *C. moniliformis*, (large, > 1 m, bushy, branching), *Sargassum* species

(subgenus *Arthrophyucus*), some *Xiphophora chondrophylla* and abundant epiphytic corallines. *Heliocidaris erythrogramma* (Val) is common in rock depressions. Near the sewerage outfall at Currie large plants (up to 15 cm diameter) of *Colpomenia sinuosa* are common; similar observations are made near the Werribee sewerage farm in Port Phillip Bay, Victoria.

Many of the species recorded for this rough water coast are none the less indicative of shelter. Table 5 indicates the situation at Currie for the main zone forming organisms.

(ii) Moderate wave action, (site 3, East coast).

The maritime zone is dominated by grasses with some succulents and there is a sharp transition to bare granite some 5 m above high tide level. The orange lichen band (*Caloplaca*) characteristic of Tasmania and E. Bass Strait islands is well developed in contrast to other localities on King Is. This could be a substrate effect since a well developed *Caloplaca* band is often, though not invariably, developed on granite.

(a) *Littoral Fringe*: *Melarapha praetermissa* is confined to crevices and *Notoacmea mayi* and *N. petterdi* are not common. Towards the inner edge of the 'reef' *Bembicium nanum* dominates the zone with *Austrocochlea constricta* in pools. *Enteromorpha* and *Austrocochlea concamerata* occur particularly where there is fresh-water inflow.

(b) *Upper Eulittoral Zone*: The pattern is similar to locally sheltered positions on the west coast. *Lichina confinis*, *Tetraclita purpurascens*, *Melanerita melanotragus* and *Siphonaria diemenensis* are common; *Siphonaria tasmanica* is absent. *Cellana tramoserica* occurs at this level but now extends through the entire eulittoral zone and *Chamaesipho columna* extends down to the *Hormosira* belt.

(c) *Mid-Eulittoral Zone*: *Galeolaria caespitosa* with epizoic *Gelidium pusillum* marks this zone with some *Rivularia firma* above. *Brachidontes rostratus* occurs in crevices but also in dense patches where flat or gently sloping rock surfaces occur above the *Galeolaria*. *Modiolus pulex* is restricted to crevices on the outer edge. Crevise pools at this level commonly contain *Actinea tenebrosa*, while larger pools support *Cystophora polycystidea* and *C. retorta* with *Caulocystis cephalornithos* occurring where there is sand.

(d) *Lower Eulittoral Zone*: *Hormosira banksii* completely dominates this zone except on the very outer edge where there is a lower sub-zone of *Cystophora torulosa*. Occasional *Codium fragile* (Suringar) Hariot, *Laurencia* species and chitons (*Poneroplax*) occur. Pools at this level are densely

TABLE 5

Distribution of some zone forming organisms with respect to local shelter at Currie, King Is.

| Rough water | Shelter |
|--------------------------------------|------------------------------------|
| <u>Durvillea potatorum</u> | |
| <u>Pseudolithophyllum hyperellum</u> | |
| <u>Melarapha paludinella</u> | |
| <u>Notoacmea mayi</u> | |
| <u>Notoacmea petterdi</u> | |
| | <u>Encrusting lithothamnia</u> |
| | <u>Cystophora siliquosa</u> |
| | <u>Chamaesipho columna</u> |
| | <u>Melarapha praetermissa</u> |
| ----- | <u>Caulerpa brownii</u> ----- |
| ----- | <u>Cellana tramoserica</u> |
| | <u>Acrocarpia paniculata</u> ----- |
| | <u>Caulerpa obscura</u> |
| | <u>Caulocystis cephalornithos</u> |
| | <u>Galeolaria caespitosa</u> |
| | <u>Cystophora polycystidea</u> |

filled with algae including *Caulerpa geminata*, *C. longifolia*, *C. simpliciuscula*, *Chaetomorpha darwinii*, *C. aerea*, *Cystophora subfarcinata*, *Hormosira* with epiphytic *Nothelia anomala* Harvey et Bailey, *Amphiroa anceps*, *Corallina officinalis*, *Jania fastigiata*, *Haliptylon subulata*, *Plocamium augustum* and all of the species listed for the upper sublittoral zone.

(e) *Upper Sub-Littoral Zone*: This zone lies immediately below the *Cystophora torulosa* band but the division is less clear in rougher parts where the *C. torulosa* is scattered. *Cystophora moniliformis*, *C. siliquosa*, and *Caulerpa brownii* dominate with *Acrocarpia paniculatum*, *Macrocystis angustifolia*, *Perithalia caudata*, *Sargassum* species and *Xiphophora chondrophylla* present. *Haliptylon subulata* is a very common epiphyte.

Ecklonia radiata was not seen growing although it is abundant in the drift.

(iii) Sheltered open coast, (site 4, Naracoopa).

(a) *Littoral Fringe*: Upper zones are truncated by sand beach. *Caloplaca* is present on the rocks but not common. *Lichina confinis* forms a conspicuous zone on open rock and animals crowd

the crevices. *Melarapha praetermissa* is abundant and *M. paludinella* is less common. *Melanarita melanotragus* is abundant into the upper eulittoral zone. *Notoacmea* species are absent.

(b) *Upper Eulittoral Zone*: *Chamaesipho columna* is present in both the upper and mid-eulittoral zones and covers up to 40% of open rock surfaces. *Tetraclita purpurascens* is common in shaded positions and crevices. *Siphonaria diemenensis* is abundant in the upper and mid-eulittoral zones and *Cellana tramoserica* occurs throughout the entire eulittoral zone. *Bembicium nanum* occurs in this zone slightly above *Austrocochlea constricta*, which is often in pools, and *A. concamerata*, in crevices. Occasional plants of *Ulva lactuca* and *Rivularia firma* occur at this level.

(c) *Mid-Eulittoral Zone*: *Cellana tramoserica* and *Chamaesipho columna* are spread throughout the zone and *Rivularia firma* is common above the *Galeolaria caespitosa*, which marks the lower limit of this belt. *Actinea tenebrosa* is common throughout the zone, and *Modiolus pulex*, with *Lepsiella vinosa*, occurs in the crevices. Pools at this level contain *Chaetomorpha aerea*, *Hormosira banksii*

with *Notheia anomala*, *Cystophora retorta* (Mertens) J. Agardh and stunted corallines. Deeper pools with sand contain *Codium fragile*, *Caulocystis cephalornithos* with epiphytic *Sphacelaria* species, *Cladostephus verticillatus* (Lightfoot) C. Agardh, and *Heterozostera tasmanica* (Mertens ex Ascherson) den Hartog.

(d) *Lower Eulittoral Zone*: *Hormosira banksii* forms a dense band and *Laurencia tasmanica* Hooker et Harvey in Harvey is common. *Cystophora torulosa* forms a characteristic lower sub-zone with individual plants up to 1 m in length. *Patelloida alticostata* is common but *P. latistrigata* is rare. *Dicathais textilosa* is scattered throughout the zone. The flora of lower pools resembles that of the upper sub-littoral zone but with increased diversity. Species other than those recorded for the sub-littoral zone are *Callipsygma wilsonii* J. Agardh, *Caulerpa flexilis* Lamouroux, *C. obscura*, *C. scalpelliformis* (R. Brown in Turner) C. Agardh, *C. sinuaticuscula*, *Codium galeatum* J. Agardh, *C. pomoides* J. Agardh, *Cystophora polycystidea*, *Pachydictyon paniculatum*, *Perithalia caudata*, *Sargassum* (sub-genus *Eusargassum*), *Zonaria turneriana*, *Jania fastigiata* and *Metagoniolithon charoides*.

Lenormandia prolifera (C. Agardh) J. Agardh is abundant in sandy pools where it is shaded by other algae.

(c) *Upper Sub-Littoral Zone*: *Xiphophora chondrophylla* forms a dense but narrow band (vertical range < 10 cm) and the encrusting coralline (MELU 20987) is commonly epiphytic. This band appears to be equivalent to the sub-littoral fringe of Womersley and Edmonds (1952). Below this, *Caulerpa brownii*, *Cystophora moniliformis* and *C. siliquosa* dominate and the entire rock surface is covered by encrusting lithothamnium. Other species present include *Caulerpa geminata*, *Acrocarpia paniculata*, *Cystophora subfarcinata* and *Sargassum heteromorphum*. *Polysiphonia nigrita*, *Haliptylon subulata* and *Jania* are common epiphytes. No *Phyllospora* or *Ecklonia* are recorded although both are found in the driftweed.

GENERAL OBSERVATIONS ON THE MARINE BIOTA OF WESTERN BASS STRAIT

(i) The absence of some common zone-forming organisms is probably due to seasonal factors, e.g. *Splachnidium rugosum* is often used as an indicator of the mid-eulittoral zone but it is not recorded here since during winter the macroscopic plant form is absent (Price and Ducker, 1966).

(ii) There is a marked similarity between the intertidal zonation of sheltered positions on rough water coasts and sheltered open coasts. More species are found on rough water coasts because

there is the possibility of a wider range of environmental conditions. Actual species density on King Is. is greater in sheltered positions.

(iii) *Notoacmea petterdi* is a common species on King Is. Bennett and Pope (1960: Fig. 3) regard it as common for the E. coast of Tasmania only but note that Kershaw (1958) records it for Stanley, N. Tasmania. Guiler (1960b) records *N. petterdi* for Trial Harbour on the W. Tasmanian coast.

AFFINITIES OF THE WESTERN BASS STRAIT MARINE BIOTA

Plants. The affinities of the W. Bass Strait flora lie with the Victorian and Tasmanian regions. The most noticeable difference from the South Australian marine flora is the presence of *Cystophora torulosa* and the large brown kelps, *Durvillea potatorum*, *Macrocystis angustifolia* and *Phyllospora comosa*. Species present on King Is. but not recorded E. of Wilsons Promontory and in S. New South Wales include 9 siphonous green algae and 5 members of the order Fucales.

Animals. The common zone forming animals on King Is. are similar to those in W. Victoria and W. Tasmania. Barnacles are reduced both in the number of species and total number and *Chthamalus antennatus* is the only common species. A similar reduction is noted in S. Tasmania and is generally attributed to the lower air and sea temperatures. Similarly, the common littorinid on King Is. is *Melarapha praetermissa*; *Melarapha unifasciata* is absent and again this species is not found on the W. or S. Tasmanian coast.

CONCLUSIONS

The pattern of zonation exhibited on the Bass Strait islands is similar to that on the southern mainland and Tasmanian coasts. The zonation pattern is more easily discernible on the smooth granite faces of E. Bass Strait islands where the tidal range is approx. 2.5 m.

The most notable feature shared by the Bass Strait islands is the sub-littoral fringe. In rough water localities in E. Bass Strait no sub-littoral fringe can be biologically justified but in W. Bass Strait *Durvillea potatorum* forms a definite fringe as it does in Victoria and Tasmania. In sheltered positions on Deal Is. and King Is. the sub-littoral fringe is characterised by the brown alga *Xiphophora chondrophylla*. This situation is not encountered on the mainland although a similar situation is occupied by *X. gladiata* in Tasmania.

The composition of the zonation pattern in King Is. is similar to that on the W. Victorian and W. Tasmanian shores. Barnacles are reduced in the number of species and total numbers when

compared with the central Victorian region and, as a consequence limpets become prominent in the littoral zone. *Melarapha praeternissa* becomes the dominant littorinid and *M. unifasciata* is absent as in W. and S. Tasmania. Where conditions are suitable broad bands of mussels are developed. The dominant kelps in the upper sub-littoral are *Durvillea potatorum* and *Macrocystis angustifolia*, both species accepted as indicators of cool temperate conditions. *Ecklonia* and *Phyllospora* are found in the drift weed but are not common.

The Eastern Bass Strait islands are under a warmer water regime and the kelps in the upper sublittoral zone include *Ecklonia radiata* and *Phyllospora comosa* both of which are characteristic on S. New South Wales coasts. In spite of the absence of *Durvillea* a number of species, generally characteristic of cool temperate waters in SE. Australia, are present, e.g. *Caulerpa brownii*, *Cyrtophora torulosa*, *Xiphophora chondrophylla* and *Ballia callitricha*.

The differences between E. and W. Bass Strait marine biotas is probably due to the generally lower sea temperatures found in W. Bass Strait. Air temperatures might be expected to follow the same trend but insufficient data are available to establish this.

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DESCRIPTION OF PLATE 10

(UPPER) Zonation pattern on sloping granite. The upper dark band of *Splachnidium rugosum* is epizoic on *Catophragmus polymerus*. The darker lower band is *Balanus nigrescens* with epizoic *Corallina officinalis*, *Dasyopsis clavigera* and *Polysiphonia* sp. The dark lichen and blue-green algal band of the littoral fringe is visible in the background. (Curtis Island, Feb. 1971).

(LOWER) Dense band of *Xiphophora chondrophylla* forming a sub-littoral fringe immediately above *Phyllospora comosa*. *Hormosira banksii* (a lower eulittoral zone species) is seen in the lower left corner. (Garden Cove, Deal Island, Nov. 1969).



MAMMALS OF THE BASS STRAIT ISLANDS

By J. H. HOPE*

ABSTRACT: Of the 31 native mammals found in Tasmania, 17 are known to be living on the islands of Bass Strait, and six introduced species have established feral populations there. Fossil deposits studied indicate that all but three of the present Tasmanian mammals (excluding the bats) were present on the islands in the past. A cave floor deposit on Flinders Island, dated at the youngest layer at about 8,000 years old, contained the remains of several species, some now extinct on the islands, as well as *Aepyprymnus rufescens*, which has not previously been recorded south of Victoria.

Subfossils recovered from sand blows in the calcareous dunes of the islands are generally the remains of species still extant on the islands, but some species now extinct there have also been found, such as *Sarcophilus harrisii*, on Flinders Island. Pleistocene fossils collected from King Island and northwestern Tasmania early this century have been reviewed. Before European settlement no island of less than 1.4 sq km supported any marsupial herbivore, while two species were found together only on islands more than 6 sq km in area. Since 1800, the populations of mammals on many of the smaller islands have died out.

Most of the species and subspecies endemic to Tasmania are present on the islands as well as in Tasmania. As the sea level fell and land was exposed in Bass Strait, the Tasmanian fauna was able to move north onto the developing land bridge and become established there long before the final connection formed with Victoria. While the land bridge was in existence the boundary between the Tasmanian and mainland faunas lay close to the present Victorian coast.

INTRODUCTION

The islands of Bass Strait are remnants of a land bridge which connected Tasmania to the mainland of Australia at times of low sea level during the Pleistocene. The modern mammalian fauna of the islands is derived from that of the most recent land bridge which broke up about 10,000 years ago (Jennings 1971). In order to understand the present distribution patterns of the island mammals, some reconstruction of the fauna of the land bridge has been made to supplement the survey of the modern fauna. Information on the late Pleistocene fauna of the area was available from fossil deposits discovered early this century on King Island and in northern Tasmania, and during this study an early Holocene bone deposit on Flinders Island was excavated. A survey of subfossils collected from the sand dunes of many islands, considered with the reports of explorers and early visitors to Bass Strait, made possible an assessment of the modern fauna of the islands prior to the effects of European settlement. Over the past 180 years both direct exploitation of

the fauna and land development have had a deleterious effect on the island fauna.

ENVIRONMENT

THE ISLANDS

Bass Strait separates the island of Tasmania from the Australian mainland by less than 200 km. The islands of the Strait are confined to two rises on the E. and W. while the deepest waters of the Strait lie in the centre. On the eastern margin of Bass Strait a chain of islands runs from the northeastern corner of Tasmania to Wilsons Promontory in Victoria. These granitic islands are generally mountainous, reaching a height of 756 m in the Strzelecki Peaks on Flinders Island. On this island a central granite spine runs from the NE. to the SW. along the island, separating a narrow western and a broad eastern coastal plain. Cape Barren Island, the second largest of the Furneaux Group, is also rugged and reaches a height of 686 m at Mt. Munro. Some of the smaller islands to the north of the Furneaux Group, such as Deal Island, the largest of the Kent Group, and

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Rodondo and Curtis Islands, off Wilsons Promontory, reach heights of up to 330 m, though they are very small in area. Of the larger eastern islands, only Clarke Island is flat and low. The widest water barrier between the islands of the eastern chain is about 50 km, separating the Kent and Furneaux Groups.

The major island on the western side of Bass Strait is King Island, midway between north-western Tasmania and Cape Otway, Victoria. In contrast to the eastern islands, King Island is a low plateau, reaching a maximum height of 168 m in the SE. To the SE. of King Island the islands of the Hunter Group lie close to the Tasmanian coast.

Tasmania, with an area of 67,900 sq km, is much larger than any of the Bass Strait islands, the largest of which are Flinders (1,333 sq km) and King (1,100 sq km.) Tasmania and the islands are physically part of the Australian continent, lying on the continental shelf. Bass Strait is shallow, with an average depth of 60 to 80 m, and a floor of subducted relief, so that a drop in sea level of only 65 m would be sufficient to expose a land corridor along the eastern islands.

CLIMATE

Tasmania and the Bass Strait islands have a temperate maritime climate controlled by the prevailing westerly winds. The following account is derived from Langford (1965) and Bureau of Meteorology (1954, 1966).

Rainfall in Tasmania is highest on the W. coast, rising to an average of over 2700 mm a year, and is lowest in the central and east coast regions where it falls to an average of less than 500 mm a year. A distinct rainshadow operates in the central, eastern and south-eastern regions, with a strong precipitation gradient across the central plateau to the adjacent midlands. This rainfall distribution can be attributed to a strong westerly circulation intensified by mountain features.

The rainshadow effect extends N. into Bass Strait, where King Island on the W. has the highest average annual rainfall of all the islands. Here the rainfall ranges from 675 mm in the N. of the island to about 1050 mm in the S. More than three-quarters of the island receives an annual rainfall of more than 850 mm. In contrast, the rainfall of Flinders Island in eastern Bass Strait ranges from 650-875 mm in different areas and is partly orographic. The Strzelecki Range is the wettest area, receiving an estimated average rainfall of 850 mm (unofficial Range figure, Dimmock 1957). Other high areas receive 750-775 mm, while most of the coastal plain receives 725-750 mm a year. Goose Island, 27 km SW. of White-

mark, Flinders Island, has an annual rainfall of 550 mm and it is likely that many of the smaller islands of the Furneaux Group have a similar low rainfall. The western coastal plain of Cape Barren Island has an annual rainfall of 675 mm, but it is probable that the higher areas of this island receive about 775 mm. The only other rainfall station in Bass Strait, on Deal Island in the Kent Group, receives an annual rainfall of 725 mm. The rainshadow effect disappears S. of the Victorian coast, where the higher coastal regions such as Wilsons Promontory and the Otway Ranges have an average rainfall of up to 1375 mm, while the lower coastal districts average 750 mm or less.

The rainfall in Tasmania, the islands of Bass Strait and southern Victoria is well distributed throughout the year, generally with a winter maximum. King and Flinders Islands differ from each other in the number of raindays as well as in average rainfall; King has an average of 212 raindays per year, in contrast with 111 raindays per year on Flinders Island.

Temperature records for Bass Strait are available only for King Island, but it is likely that a similar regime occurs on Flinders Island as well. On King the mean maximum temperature for summer is about 20°C. Extreme maxima are just above 35°C, but days over 32°C are rare. The mean winter temperature is 13°C. Minimum temperatures average 12°C in summer and 7°C in winter. Extreme minima of below 0°C occur occasionally in winter and spring, but frosts are rare and near the sea many years may be frost-free.

The prevailing winds in Bass Strait and Tasmania are from the NW. and SW., and are strongest from the W. From this direction, in the Strait, winds blow with great severity and gales may last for several days with calm spells in between. Northwest winds are stronger and more frequent in winter, while those from the SW. are more frequent from October to February.

VEGETATION

The climatic gradient gives rise to some distinctions in the vegetation of the eastern and western islands. Wet sclerophyll forest, locally dominated by *Eucalyptus globulus* originally extended over the SE. of King Island (Green & McGarvie 1971) but has now been completely destroyed by fire. On Flinders and Cape Barren Islands it is restricted to sheltered mountain gullies (Green 1969). Dry sclerophyll forest, dominated by *E. viminalis*, *E. ovata* and *E. amygdalina*, which generally occurs in areas of less than 750 mm annual rainfall, covers the central hills of the Furneaux Group. Eucalypt woodlands, dominated by *E. ovata* and *E. simmondsii* also occur on

shallow or poor soils on these islands and others of more than 5 sq km. in area. On exposed headlands or calcareous sands *Casuarina stricta* forms extensive woodlands often with a shrubby understorey, and this community is a characteristic component of island vegetation extending to the smaller groups such as the Kent, Glennie, and Seal Groups.

Myrtaceous shrublands and various heath communities are widespread on many islands, especially on coastal dune fields or on very poor soils associated with leached sand sheets. Very dense fire-seral shrublands have replaced the original forests and woodlands in many areas. *Melaleuca ericifolia* forms dense thickets on waterlogged ground and these are especially extensive on King Island. Closed *Poa poiformis* tussock grassland is the major community on the smaller or more exposed islands, although it can also be extensive as a coastal belt on the larger islands such as Cape Barren Island. Guiler (1967) has suggested that some smaller islands in the Furneaux Group now vegetated by *Poa* grassland once carried shrublands and woodlands which have been removed by clearing and firing. The vegetation on most islands has been regularly burnt and large areas of Flinders and King Islands have been cleared and pastures established. Green (1969) and Green and McGarvie (1971) have described the modern disturbance of the vegetation on these two islands.

EUROPEAN SETTLEMENT

Bass Strait was one of the earliest parts of Australia to be settled during the late 18th and early 19th centuries, attracting a large itinerant population because of the abundant seals on the islands. When the seals were virtually wiped out by the 1830's, many of the sealers remained on the islands, farming, fishing and hunting. The smaller islands of the Furneaux Group were inhabited almost continuously until the 1930's, and are still used for grazing or for the seasonal industry, muttonbirding. The larger islands, Flinders and King, were not inhabited to any great extent until the end of the 19th century, apart from the short-lived aboriginal settlement on Flinders Island in the 1830's (Plomley 1966). Recent War Service Land Development schemes have led to extensive land development on both these islands. The history of land settlement has been given in some detail by Stephens and Hosking (1932) for King I., and by Dimmock (1957) and Pryor (1967a, b) for Flinders I.

PAST CONDITIONS

During the last glacial period of the Pleistocene

when the world sea level was somewhere between 100 and 150 m lower than at present, an extensive land bridge, incorporating the islands of Bass Strait, existed between southern Victoria and Tasmania. Jennings (1959b, 1971) has discussed in detail the formation and disappearance of the land bridge.

Although the full extent of Bass Strait may have been land only for a short time at the maximum of the final glaciation, the broad Bassian Rise between Wilsons Promontory and Flinders Island probably remained above sea level for much longer, though it may have been broken for some time during interstadials when the sea level rose. Jennings (1971), applying the glacioeustatic curves of several authorities, has suggested ranges of dates for the postglacial break of the land bridge and the subsequent isolation of the islands from Tasmania, but has stressed the uncertainty of these with respect to possible tectonic movements and erosion and sedimentation in Bass Strait.

At the end of the glaciation, the rising sea would first have broken the connection between King Island and the Otways and then spread into the Bassian Depression between King and Flinders Islands. The break between Victoria and Flinders Island probably occurred between 10,000 and 15,000 years ago, but the bulk of the estimates obtained from using different glacioeustatic curves lies between 12,000 and 13,500 BP. Since this is the period of sharp oscillations in climate and ice limits in the northern hemisphere, it is possible that the sill between Victoria and Flinders Island was flooded then re-exposed at this time, before finally submerging. For the King Island Rise, between King Island and NW. Tasmania, a similar range of dates was obtained, with the preponderance here between 10,000 and 12,500 BP. Similarly the link across Banks Strait, between the Furneaux Group and Tasmania, may have been lost between 8,500 and 10,000 BP.

The sea level rose sharply to reach its present level about 6,000 years ago, but there is some controversy as to whether it has since then remained stationary, oscillated slightly or whether there has been a small but persistent rise. The islands of the Furneaux Group are separated from each other by depths of less than 17 m, so it is likely that many were not isolated from each other until this time. If there has been any oscillation in sea level during the last 6,000 years, then the islands of the Furneaux Group and of the Hunter Group may have been periodically joined and separated. Shifting sand bars and shoals may have complicated this effect; within historical times connections have existed between some

islands in the Furneaux Group and between Robbins and Walker Islands in the Hunter Group.

The temperature in Tasmania during the last glaciation was probably about 5°C lower than at present (Galloway 1965), but there is conflicting evidence as to whether the climate in Australia was wetter or drier at the time. Geomorphological evidence (Davies 1967) suggests that the precipitation gradient across Tasmania was at least as marked during the last glaciation as it is today. If so, it is likely that the rainshadow effect would have extended north onto the Bassian land bridge, perhaps accentuating the present difference in rainfall between the eastern and western islands. There is evidence that the climate was at least effectively wetter in this region, as Jennings (1959a, 1961) records wood of *Nothofagus* sp. and pollen of *N. cunninghamii*, *Phyllocladus aspleniifolius* and *Drimys lanceolata*, all constituents of the cool temperate rainforest, from a deltaic deposit on King Island dated at $37,500 \pm 1900$ years BP.

Within Tasmania a 5°C drop in temperature would have brought the tree line down to 500 m above sea level, according to Galloway (1965). Since Tasmania is mountainous, this would have restricted forest and woodland to a narrow fringe around the coast, the central midlands and the land bridge to the north. In higher areas towards the permanent snowline, only alpine communities would have survived. Cool temperate rain forest probably extended into lower areas of Tasmania and onto the land bridge. However, areas of dry sclerophyll forest and woodland must have persisted during the glaciation, as five endemic eucalypts are found today in these communities in eastern Tasmania (Jackson 1965). Little definite evidence is available about Pleistocene vegetation within Tasmania, even though Gill and Banks (1956) have suggested that pollen evidence indicates that an open woodland existed at Mowbray Swamp, in northwestern Tasmania, dated at more than 37,000 years BP.

PLEISTOCENE FOSSILS FROM KING ISLAND AND TASMANIA

King Island (Fig. 1) is a low plateau, largely of metamorphic rocks, with superficial Cainozoic deposits of limestones, calcarenites and sand. The main plateau reaches its maximum height of 168 m in the SE., and with its low surface of rolling hills, extends N. for about two-thirds of the island. At the N. of the island, the coastal sand dunes surround a low area of lagoon and swamp land. Jennings (1959a) describes in detail the geomorphology of this area, which consists basically of estuarine-marine deposits overlain in places by freshwater and swamp deposits.

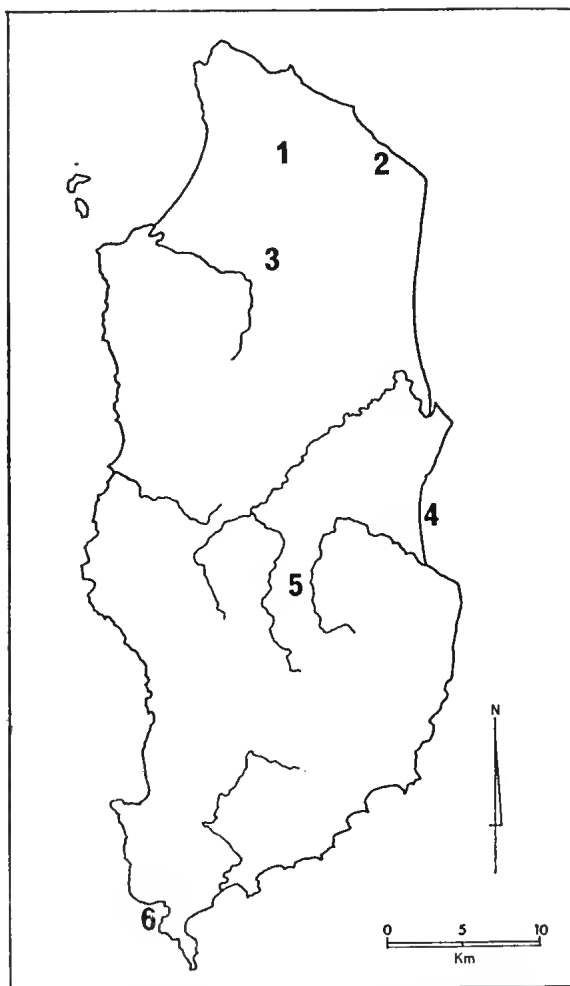


FIG. 1—King Island. 1. Egg Lagoon. 2. The Nook. 3. South East Lagoon. 4. Sea Elephant Bay. 5. Pegarah. 6. Surprise Bay.

In the process of draining the two major lakes in this area, Egg Lagoon and South-East Lagoon, early this century, several finds of fossil marsupials were made. Scott (1912, 1915a) identified bones from King Island, sent to him by F. H. Stephenson of 'Yambacoon' Station, as *Nototherium victoriae* Owen. Jennings recorded that Mr. H. Graves of King Island had told him that the find was actually made in 1911 by Mr. Graves' brother, at the western end of Egg Lagoon. Further comments on this material were made by Scott and Lord (1921b, c, d). Kibble (1945) described another find from Egg Lagoon of bones attributed to *Diprotodon australis*, made by Mr. J. G. Haynes in 1927. The bones were found scattered along a quarter of a mile of drain in clay underlying black swamp soil. This collection is in the National Museum of Victoria and includes a molar of *D.*

optatum (= *D. australis*) (P14403), skull and mandible fragments of *Protemnodon anak* (P30786) and some unidentified long bones. Jennings (1959a) gave some details of the stratigraphy of peats and clays from the sites of these two finds.

A further collection, made by the surveyor, K. M. Harrison, has been attributed by Jennings (1959a) to South-East Lagoon, although it is very poorly documented. Scott and Lord (1922c, 1924a, b, c) recorded from this locality *Zaglossus harrissoni* Scott and Lord, *Nototherium mitchelli* Owen, *N. victoriae* Owen and *Macropus anak* Owen, as well as modern wombats, wallabies and kangaroos. Fossil material in the Queen Victoria Museum, labelled 'Harrison's Collection' includes the modern species *Vombatus ursinus*, *Thylagale billardierii*, *Dasyurus maculatus* and probably also *Macropus rufogriseus*. Jennings considered that the freshwater deposits of South-East lagoon and possibly also Egg Lagoon must date back to the formation of the series of older coastal dunes, possibly during the last interglacial period of the Pleistocene.

A similar series of fossils has been collected from Mowbray Swamp in the NW. corner of Tasmania. Here the fossils were recovered from peats overlying an Upper Pleistocene marine sand. In 1910, fossils recovered from Mr. E. C. Lovell's farm were described as a new species, *Nototherium tasmanicum* Scott 1911 (Scott & Harrison 1911, Scott 1915a, Scott & Lord 1921b, 1922a, 1923, 1924d, 1925a, b, 1926; Noetling 1912). Later *Palorchestes* was recorded from Mowbray Swamp (Scott 1916), as well as *Nototherium mitchelli* (Scott & Lord 1921a, b, c, d, 1922a, 1923, 1925a, b) and *Phascolonus* (Scott & Lord 1925b). The remains of *Vombatus* sp., kangaroo, wallabies and rodents have also been found there (Gill & Banks 1956). Scott (1927) gave a general account of the finds.

Gill and Banks (1956) have written a detailed review of the fossils and have investigated the geomorphology of Mowbray Swamp. They obtained a ^{14}C date of more than 37,000 years BP from peat at the site of discovery of the holotype of *N. tasmanicum*. On the assumption that the large marsupials found here would have been associated with a more open vegetation than the thickets which covered Mowbray Swamp before clearing this century, they suggested that these deposits formed during a period drier than the present. Gill and Banks (1956) also recorded the discovery of extinct species of marsupials from Scotchtown Cave, a few miles from Mowbray Swamp. These include the following: *Nototherium*, *Thylacoleo*, *Palorchestes*, *Sthenurus*, *Macropus* aff.

titan, *Vombatus*, *Thylacinus*, *Sarcophilus* and wallaby. Tedford (1966) considered the *Sthenurus* from this deposit to be *Sthenurus occidentalis*.

These records suggested that there were three diprotodontids present on King Island during the Pleistocene (*Diprotodon optatum*, *Nototherium mitchelli*, and *N. victoriae*) and three present within Tasmania (*N. mitchelli*, *N. tasmanicum* and *Palorchestes azael*). This led to some zoogeographic speculation, for example by Woods (1962) who suggested that the apparent absence of *Diprotodon optatum* from Tasmania might have been due to the presence of the endemic species *Nototherium tasmanicum*.

However, although no detailed studies have yet been carried out on the collections of Pleistocene material from King Island and Tasmania, some of the above identifications are now known to be incorrect. Most importantly, the holotype of *Nototherium tasmanicum* Scott from Mowbray Swamp (QVM 1965/39/2), has been identified by the late R. A. Stirton as a specimen of *Zygomaturus trilobus* (M. Plane, pers comm.). The specimen described and figured as *Nototherium mitchelli* by Scott and Lord (1921c, d, Plates XIII-XXIII) also seems to be *Z. trilobus*. Stirton (1967) and Woods (1968) have discussed the status of the various described species of *Nototherium*, and it is likely that only one species was represented in the known Pleistocene faunas. Further study of the fossil material from King Island and Tasmania is needed to discover what material is in fact *Z. trilobus* and what, if any, is attributable to *Nototherium*. Pending this, the record of *Nototherium* for King Island and Tasmania is retained here.

As *Zygomaturus trilobus* is found throughout southern Australia in Pleistocene deposits, and *N. inerme*, *Diprotodon optatum*, and *Palorchestes azael* are also well represented in the mainland Pleistocene faunas, it seems that, unless further fossil discoveries prove otherwise, the Pleistocene marsupial fauna of Tasmania and King Island included no species peculiar to that area. This leaves *Zaglossus harrissoni* as the only fossil mammal which can be considered endemic to the Pleistocene of Tasmania. It is represented, however, only by one femur, and a revision of Pleistocene species of *Zaglossus* throughout Australia is likely to show that this King Island species is no different from the mainland ones.

RANGA CAVE, FLINDERS ISLAND

Pleistocene aeolian calcarenites occur over much of the W. coast of Flinders Island and have been described in detail by Sutherland and Kershaw (1971). A cave is developed in the limestone of

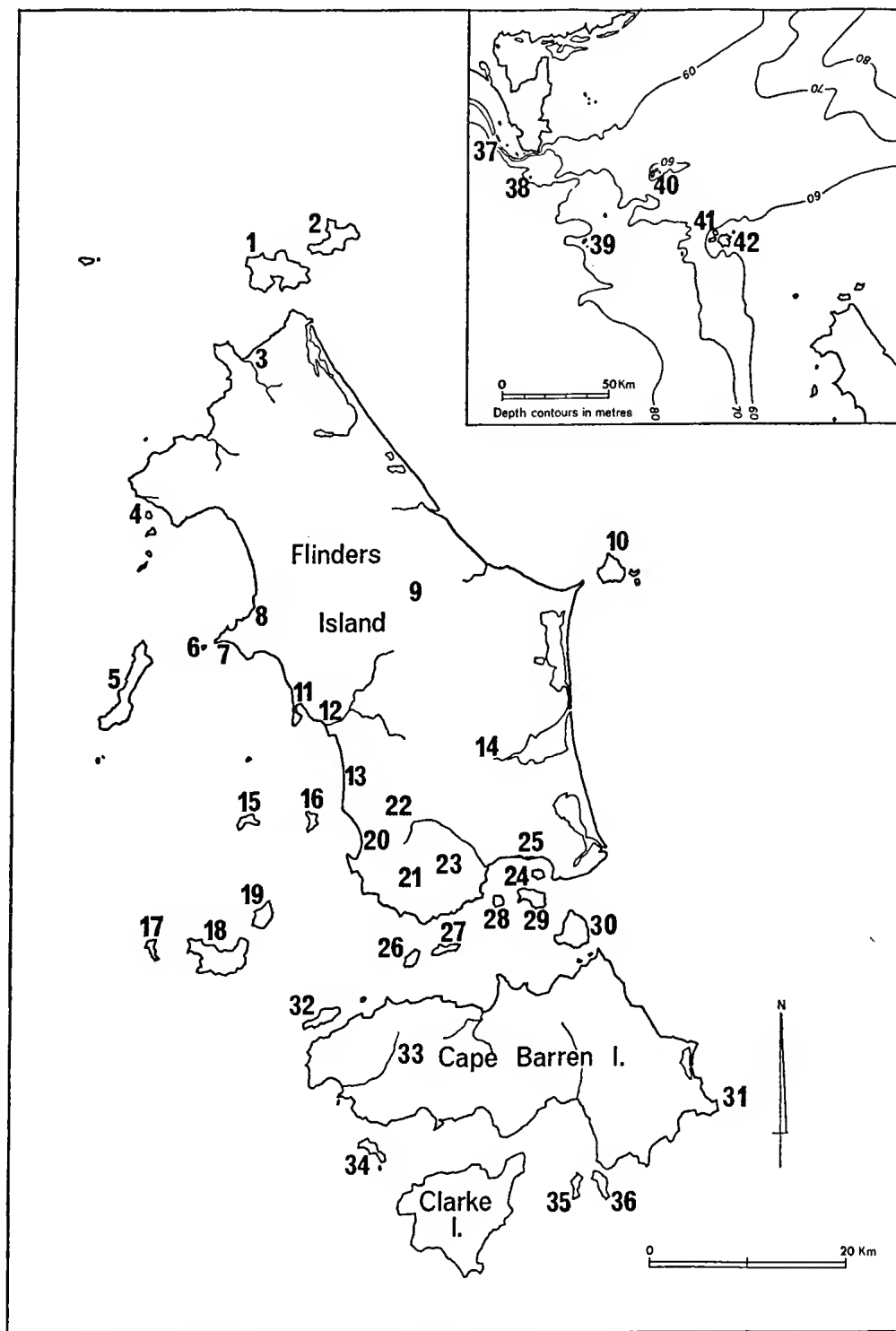


FIG. 2—Islands of eastern Bass Strait. 1. West Sister I. 2. East Sister I. 3. Palana. 4. Roydon I. 5. Prime Seal I. 6. Wybalena I. 7. Settlement Point. 8. Emita. 9. Memana. 10. Babel I. 11. Blue Rocks. 12. Pats River. 13. Whitemark. 14. Lackrana. 15. Big Green I. 16. East Kangaroo I. 17. Goose I. 18. Badger I. 19. Mt. Chappell I. 20. Locotta. 21. Strzelecki Peaks. 22. Ranga Cave. 23. Smiths Gully. 24. Little Green I. 25. Lady Barron. 26. Woody (Anderson) I. 27. Tinkettle I. 28. Little Dog I. 29. Big Dog I. 30. Vansittart I. 31. Cape Barren. 32. Long I. 33. Mt Munro. 34. Preservation I. 35. Forsyth I. 36. Passage I. 37. Glennie Group. 38. Rodondo I. 39. Curtis I. 40. Hogan Group. 41. Erith I. 42. Deal I.

a dune at Barclay's Hill, near Ranga in the south of Flinders Island (Fig. 2). This cave, here called Ranga Cave, has long been known on Flinders Island; several bones recovered from its floor were sent to the Queen Victoria Museum in 1917 by F. Henwood and L. L. Waterhouse (Scott & Lord 1922b). These consisted of the remains of *Vombatus ursinus*, *Macropus rufogriseus*, *Potorous tridactylus* (= *P. apicalis*) and *Trichosurus vulpecula*, as well as a phalange of the fur seal, *Arctocephalus tasmanicus* (= *A. doriferus*) (Sutherland & Kershaw 1971).

The calcarenite dune at Ranga is on the western side of the island and fills a valley between granite hills, lapping onto the foothills of the Strzelecki Peaks. The cave is developed in the steep north bank of a creek running W. between the granite range to the S. and the limestone to the N. At this point the hillslope is gentle enough to maintain a soil cover and is vegetated in areas between limestone outcrops, but further W. a sheer walled gorge is developed. No other caves are known from Flinders Island, but several sinkholes occur above the cliffs to the W. of Ranga Cave. Sinkholes have been known to open up after heavy rain elsewhere on the property at Barclays Hill which includes the limestone dune.

Ranga Cave is about 45 m above sea level and 12 m above the present creek. It consists of a single domed chamber, extending in an E.-W. line for 22.5 m and it averages 9 m in width. At the eastern end an extension adds another 7.5 m in length. The extension appears to be a cavity amongst fallen blocks of limestone that is now isolated from the main cave by the formation of a wall and roof of calcite about 2 m high. Ranga Cave has a low narrow entrance at floor level on the S. side of the cave. Within the main chamber several large pillars extend from floor to ceiling, and stalactites and stalagmites are common. The walls and formations are covered with wet milk calcite. The floor of the cave is earthen, covered in places by a thin layer of calcite and large pieces of fallen stalactite. The floor slopes from W. to E., falling about 2 m in the length of the cave. Entry to the small extension is gained through a hole in the rock shelf acting as its roof, and beyond it the eastern end of the cave is blocked by fallen rocks. At the western end a narrow passage about half a metre high leads off from the cave. By excavating the floor it was possible to crawl about 10 m. The passage then expanded into small chambers and branched in all directions.

Animal remains collected from Ranga Cave came from two sources. The remains of smaller animals, mainly rodents, were recovered from crevices within the isolated extension. These were

generally well preserved skulls and undamaged long bones. Some were coated with or cemented together by calcite. In contrast the bone material recovered from excavation in the floor of the main part of the cave consisted of both large and small species and was very fragmented.

Altogether four pits were dug in the floor, three at the lower eastern end of the cave and one at the western end. The section in Table 1 describes the deposit at the eastern end of the cave. In the most easterly pit the large rocks appeared at a depth of 60 cm and there was no observable change from red to brown earth. In the pit at the western end of the cave, a similar sequence to that in Table 1 was observed. Although the top of this pit was about 2 m higher than those excavated at the eastern end, the width of each layer in the deposit was much the same, and it appeared that the sediments dipped from west to east following the slope of the floor. Very little bone was recovered from the eastern pit.

Because of the floor slope, it would seem that the floor material with its bone and abundant charcoal had been washed into the cave from the western end. No pollen was found in the deposit. There was a change at 60 cm from an upper red earth to a lower brown one. At that point the quantity of quartz and mineral sand decreased from about 50 % (by volume) to about 25 %, and there was a very low amount of carbonate in soil samples in the brown earth. Charcoal and to a lesser extent bone was concentrated in the red earth and

TABLE 1
PROFILE OF EXCAVATION AT RANGA CAVE,
FLINDERS ISLAND

| Description | Depth |
|--|-----------|
| 1. Compact dark brown layer | 0-1 cm |
| 2. Very light yellow layer with abundant bone fragments and charcoal. Carbon-14 date on charcoal from this layer is $8,110 \pm 340$ BP (GaK 1300). | 1-2 cm |
| 3. Loose dry red earth, with abundant bone fragments and charcoal. A few small rocks of limestone. Carbon-14 date from charcoal in the top 15 cm of this layer is $8,200 \pm 120$ BP (GaK 1301). | 2-60 cm |
| 4. Wet brown earth, very little charcoal, many bone fragments. Large irregular rocks and pieces of stalactite. | 60-90 cm |
| 5. Large limestone boulders, with wet brown earth between. Unknown depth. | 90-180 cm |

surface layers and it was impossible to collect enough charcoal for a radiocarbon date from the brown earth. The two radiocarbon dates obtained from the upper layers are listed in Table 1.

Bone was recovered from the floor by drying the excavated earth and then sifting it. Almost all the bone collected from here was very fragmented, consisting of small chips and isolated teeth. The type of bone fragmentation is the same as that found by Douglas, Kendrick and Merrilees (1966) in a bone deposit near Perth, W.A., and interpreted by them to be due to predation by the Tasmanian devil, *Sarcophilus harrisii*. Although this species is not represented in the cave deposit and has not been recorded alive on Flinders Island, it has been found as a subfossil there. The bones recovered from the small extension are less fragmented and may represent animals that had fallen into the cave from some old opening to the surface. Identifications are generally based on teeth, and because of the fragmentation identifiable material was rare. All species recorded from the excavated pits were collected both in the red and brown layers, but no estimate of the relative abundance at the different levels was possible. Most of the animals in the deposit were either juveniles or aged specimens, as shown by the state of eruption and wear of the teeth.

The mammal species fall into three categories:

- a. Those which are found on Flinders Island at present. All of these are part of the modern Tasmanian fauna. These are *Macropus rufogriseus*, *Thylogale billardieri*, *Vombatus ursinus*, *Potorous apicalis*, *Trichosurus vulpecula*, *Pseudocheirus peregrinus*, *Rattus lutreolus* and *Antechinus minimus*.
- b. Those which have never been recorded alive on any of the Bass Strait islands, but which are still present in Tasmania. These are *Macropus giganteus*, *Perameles gunnii*, *Dasyurus viverrinus*, *Mastacomys fuscus* and *Pseudomys higginsii*.
- c. Those which have never been recorded alive from either the islands or Tasmania. These are *Aepyprymnus rufescens* and *Pseudomys cf. novaehollandiae*. The latter has been recorded from a cave deposit at Flowery Gully, Tasmania, dated at 7080 ± 420 years BP (Green 1967, Gill 1968) and it may be that *Aepyprymnus* is also represented in the fossil Tasmanian fauna, but it has not yet been recorded. Both these species are represented in cave faunas of southern Victoria but *Aepyprymnus* was last recorded alive there during the 19th century (Wakefield 1964). Although *Pseudomys novaehollandiae* was also thought to be extinct in Victoria, a small colony

has recently been discovered on the Mornington Peninsula (Seebeck & Beste 1970).

The final separation of the eastern Bass Strait islands from Tasmania probably occurred some time between 8,500 and 10,000 years ago (Jennings 1971), after the islands had already been cut off from Victoria. The age of the topmost layers of the deposit at Ranga Cave is about 8,000 years BP and it is probably that the deposit accumulated over at least several hundred if not some thousands of years. So the species found in the deposit represent a selection of the fauna of the eastern side of the Bassian peninsula at the time of sea level rise and island formation. This fauna appears to have been largely the same as that of Tasmania today. There are only two additional species represented which do not now live in Tasmania and one of these is known as a fossil from Tasmania.

SUBFOSSILS FROM THE ISLAND SAND DUNES

As with much of the southern and western coasts of Australia, aeolian calcarenites are found on many of the islands of Bass Strait. In many places unconsolidated sand dunes overlie the limestones, and where blowouts occur in these dunes, accumulations of the bones of mammals and birds have often been exposed. Flinders (1814 p. cxxxii) described one of these blowouts on Preservation Island in the Furneaux Group as 'remarkable for the quantity of bones of birds and small quadrupeds, with which it was strewed'.

The extensive dune systems attracted the attention of members of the several Victorian Field Naturalists' expeditions to Bass Strait, and in the 1880's subfossils were collected from King and Deal Islands. Later Spencer and Kershaw (1910a) described an extensive collection from Stokes Point on the extreme SW. corner of King Island. Similar deposits have now been found in sand blows on Flinders and Cape Barren Islands, as well as on several of the smaller islands of the Furneaux Group. In comparable coastal sand dunes in Victoria and Tasmania, Aboriginal midden material has been found (Coutts 1967, Jones 1968), but there are no indications of the presence of Aborigines, such as broken and burnt shells and charcoal, in the island dunes. However, one stone implement has been collected at Palana, and a few others found elsewhere in the Furneaux Group (R. Jones, pers. comm), although the islands were not inhabited by Aborigines when they were first visited by European explorers.

Jennings (1968) has discussed the distribution and formation of calcarenites in southern Australia, with particular reference to Bass Strait. Here, on the larger islands the west coast dunes are predominantly calcareous, ranging from unconsolidated shell sand to a typical calcarenite, while those on the eastern coasts consist mainly of quartz sand. On King Island Jennings (1959a) distinguished new and old dune systems. The latter are mainly siliceous, consisting of deeply leached white sand, often overlying a humus-bound sand rock. Calcareous old dunes on the western side of King Island occur down to sea level. Calcarenite exposed within new dunes may belong either to the new dune or to the underlying old dune. Kershaw and Sutherland (1971) have found a similar pattern in the dune systems of Flinders Island, but suggest that there the old dunes could comprise up to five series of different ages. There is no agreement as to whether the present coastal dune systems formed during the glacial periods, when the sealevel was lower than at present, or during periods of high sealevel, that is, interglacials and interstadials. Jennings (1959a) considered that the immaturity of the soil profile of the new dunes on King Island indicates that they are Holocene, while he places the old dunes in the last interglacial on the evidence of high sealevel features. The dunes on Flinders I. are probably of similar and older ages. Fossil marsupials have been recovered from both calcarenites and from blowouts in unconsolidated sands.

KING ISLAND

The list of species recorded from the King Island sand dunes (Table 2) has been compiled from Spencer and Kershaw (1910a), Scott (1905, 1906, 1917) and Anderson (1914), as well as from the extensive collections in the National Museum of Victoria, the Tasmanian Museum, Hobart, and the Queen Victoria Museum, Launceston.

The first fossil specimen from Surprise Bay, King Island, was identified by Scott (1905) as *Macropus anak* Owen. At the same locality, Scott also recorded specimens which he first called '*Procoptodon*' (Scott 1906) but later identified as *Sthenurus atlas* (Scott 1917). Anderson (1932) considered this to be *Sthenurus occidentalis*, and Tedford (1966) agreed with this identification. According to Scott (1905) these fossils were 'embedded in a soft friable (shell) limestone rock, of marine origin'. Jennings (1959a) interpreted this matrix as calcarenite. These two species described by Scott seem to be

the only ones recovered from calcarenites and sand dunes on the islands that were certainly extinct before Europeans arrived in Bass Strait in 1797.

The collections of Spencer and Kershaw, and most of the material in museum collections consist of the remains of animals still alive on King Island today, or which have only recently become extinct there. These specimens were not embedded in calcarenite, but were found scattered throughout unconsolidated sand dunes. Of these *Vombatus ursinus* and the King Island emu *Dromaius ater* were seen alive by French naturalists in 1802 (Péron & Freycinet 1816 p. 13), but had apparently died out on the island by the time of the 1887 Field Naturalists' expedition (Campbell 1888). Spencer and Kershaw (1910a) also described an endemic species of tiger cat, *Dasyurus bowlingi*, from the subfossil material of King Island. This is not in fact specifically distinct from *Dasyurus maculatus* (Marshall & Hope 1973).

Apart from these species, and *Pseudomys higginsii*, which has never been recorded alive from King Island but may possibly still survive in the wet gullies in the southeast of the island, all other species listed in Table 2 are still extant there.

FURNEAUX GROUP

Although calcareous dunes extend down much of the W. coast of Flinders Island, most of them are stabilized. The only extensive sand blow is at Palana on the north coast, from where the largest collection of subfossils has been recovered. This blowout is evidently very old, as sand hills are marked at Palana on the Admiralty Charts compiled by Stokes between 1839 and 1842, before Flinders Island was leased for settlement. However new areas at Palana are now actively eroding due to cattle grazing.

The Palana blow extends for about 3 km along the coast. A thin limestone band runs through the sand dunes, and Kershaw and Sutherland (1971) consider that this outlines the profile of older dunes lying beneath the superficial unconsolidated sands. This thin layer which dips from E. to W. is partly eroded through at the western and older end of the blow, where the floor of the sand blow, except for a low fore-dune, is almost continuous with the modern beach, and slopes gently upwards away from the shore. Here driftwood and marine shells are intermixed with mammal and bird bones. Towards the E. the blowout is more recent, and has uncovered the limestone layer at about 9 m above sea level. Large boulders of Palana Limestone (calcarenite) outcrop in the

TABLE 2
SPECIES RECORDED FROM THE SAND DUNES OF THE ISLANDS OF
BASS TRAIT

K —King I.
F —Flinders I.
C —Cape Barren I.

Ps —Passage I.
Pr —Preservation I.
Ka —East Kangaroo I.

D —Deal I.
E —Erith I.
T —Three Hummock I.

| Species | K | F | C | Ps | Pr | Ka | D | E | T |
|----------------------------------|---|---|---|----|----|----|---|---|---|
| TACHYGLOSSIDAE | | | | | | | | | |
| <i>Tachyglossus aculeatus</i> | + | + | - | - | - | - | - | - | - |
| DASYURIDAE | | | | | | | | | |
| <i>Antechinus minimus</i> | + | ? | - | - | ? | - | ? | - | - |
| <i>Dasyurus maculatus</i> | + | + | + | - | - | - | ? | - | - |
| <i>Sarcophilus harrisii</i> | - | + | - | - | - | - | - | - | - |
| PERAMELIDAE | | | | | | | | | |
| <i>Isodon obesulus</i> | - | + | + | + | - | - | - | - | + |
| PHALANGERIDAE | | | | | | | | | |
| <i>Trichosurus vulpecula</i> | - | - | - | + | - | - | + | + | - |
| PETAURIDAE | | | | | | | | | |
| <i>Pseudocheirus peregrinus</i> | + | + | + | - | - | - | - | - | - |
| VOMBATIDAE | | | | | | | | | |
| <i>Vombatus ursinus</i> | + | + | + | - | - | - | + | - | - |
| MACROPODIDAE | | | | | | | | | |
| <i>Potorous apicalis</i> | + | + | + | - | - | - | + | - | + |
| <i>Thylogale billardierii</i> | + | + | + | + | - | + | + | + | + |
| <i>Macropus rufogriseus</i> | + | + | + | - | + | - | + | + | - |
| <i>Macropus giganteus</i> | - | - | - | - | - | - | ? | - | - |
| <i>Protemnodon anak</i> | + | - | - | - | - | - | - | - | - |
| <i>Sthenurus occidentalis</i> | + | - | - | - | - | - | - | - | - |
| MURIDAE | | | | | | | | | |
| <i>Rattus lutreolus</i> | + | + | + | + | + | - | + | + | - |
| <i>Pseudomys higginsii</i> | + | - | - | - | - | - | - | - | - |
| OTHERS | | | | | | | | | |
| <i>Dromaius ater</i> | + | - | - | - | - | - | - | - | - |
| <i>Puffinus tenuirostris</i> | + | + | + | + | + | + | + | + | - |
| <i>Cereopsis novaehollandiae</i> | - | - | - | - | + | + | - | - | - |
| <i>Tiliqua nigrolutea</i> | ? | + | + | + | + | - | + | + | - |
| Cattle/Sheep | + | + | + | + | + | + | - | + | - |
| Rabbit | - | - | - | - | - | + | - | + | - |
| Seal | ? | - | + | - | + | - | - | - | - |

sand below the limestone layer about halfway along the blow, and other outcrops occur further to the E.

Almost all the mammals and birds represented in the sand blow are present on Flinders Island today. *Dasyurus maculatus* and *Potorous apicalis* are now very rare, and another two species are not now present on Flinders Island. One of these, *Isoodon obesulus*, exists in Bass Strait only on West Sister Island about 6 km N. of Palana. The other species is *Sarcophilus harrisii*, which has not been recorded from elsewhere in Bass Strait, though it is still common in Tasmania. The only notable absence from the collection is *Trichosurus vulpecula* which is very common on Flinders Island today.

On the east coast of Cape Barren Island blow-outs exist at Cape Barren and at Harleys Point, about 12 km to the N. At the former locality the eroding sand ridges run along an E.-W. axis, parallel to the S. coast of the island. Although on the E. coast of the island, they are calcareous, and there are many calcified rootlets in the dunes. The species collected from this sand blow are much the same as on Flinders Island. *Isoodon obesulus* and *Potorous apicalis* have not been recorded from Cape Barren Island before, and it is possible that they are both still extant, as the island has been little explored. *Vombatus ursinus* is now extinct on Cape Barren Island, and *Trichosurus vulpecula*, absent from the sand blow here as on Flinders Island has never been recorded from Cape Barren Island.

At Harleys Point very fragmented bones of seal and of *Thylogale billardierii* were collected. These were stained a deep red colour, in contrast to the bones from the Cape Barren sand blow which were bleached white.

Two small islands to the S. of Cape Barren, Passage and Forsyth Islands, are both dissected by sand blows. The animal bones collected from Passage are listed in Table 2. Particularly notable is the presence of *Trichosurus vulpecula*, which has not been collected from the dunes of the three larger islands. It is unlikely that any large mammals are still extant on Passage Island.

Although Preservation Island is well vegetated, there are two small areas of erosion from which bones have been collected. Preservation is the only one of the smaller islands of the Furneaux Group from which the remains of *Macropus rufogriseus* have been collected.

A collection of thylogale skulls from Kangaroo (East Kangaroo) Island was made by J. A. Kershaw in 1909. These specimens, now in the collection of the National Museum of Victoria are

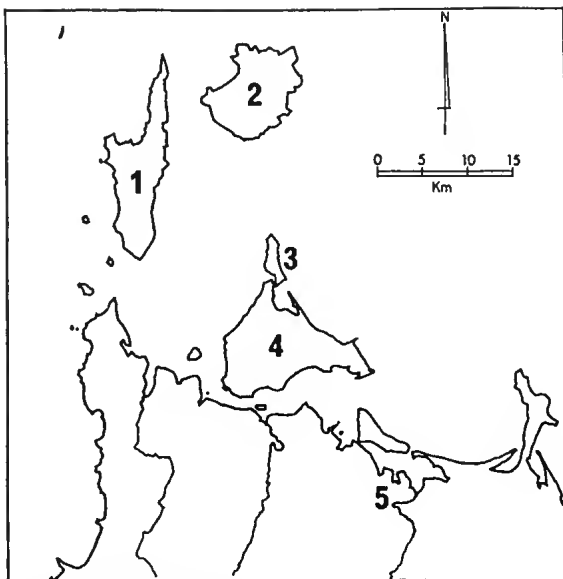


FIG. 3—Hunter Group. 1. Hunter I. 2. Three Hummock I. 3. Walker I. 4. Robbins I. 5. Mowbray Swamp.

labelled as coming from a 'sand blow, formerly timbered hill'. Barrett (1918 Vol. 2, p. 126) described this extensive sand blow on Kangaroo Island in 1909. It contained seal and sheep bones, as well as wallaby.

Seal bones, probably of the fur seal, *Arctocephalus doriferus*, which once inhabited the smaller islands of the Furneaux Group, have been found on Roydon Island. No remains of terrestrial mammals have been collected.

HUNTER GROUP

The islands of the Hunter Group (Fig. 3) are the only ones in Bass Strait known to have been visited by the Tasmanian Aborigines. Flinders (1814) recorded several deserted fireplaces on Three Hummock Island and Meston (1936) gives an account of Aboriginal middens on the islands of the group. He mentions that bones of marsupials and birds were found in the sand blows, associated with shells. The collections of the National Museum of Victoria include bones of *Thylogale billardierii*, *Isoodon obesulus* and *Potorous apicalis*, labelled '3 Hummock Island', and dated 24.11.08-9.12.08, the dates of the A.O.U. expedition to Bass Strait (White 1909).

KENT GROUP

The Kent Group lies to the N. of Bass Strait, between the Furneaux Group and Victoria. The first subfossils from these islands were collected by members of the expedition run by the Field Naturalists' Club of Victoria in 1890 (Le Souef

1891). At Winter Cove on the eastern side of Deal Island, many bones were found loose on the floor and protruding from the walls of a gully. Le Souef recorded the marsupials *Thylogale billardieri* and *Macropus giganteus* from this gully, but most of the remains were bird bones. Spencer and Kershaw (1910a) recorded as subfossils from Deal Island, *Vombatus ursinus* and a tiger cat, which they thought to be similar to the species *Dasyurus bowlingi* they had described from the sand blows on King Island. Neither of these two latter species, nor *Macropus giganteus* has ever been recorded alive from the Kent Group. No specimen of *Macropus giganteus* or *Dasyurus maculatus* from Deal Island could be found in the National Museum of Victoria which houses the collections of Spencer and Kershaw and of the Field Naturalists' Club expeditions. The museum collection does contain specimens of *Thylogale billardieri*, *Macropus rufogriseus*, *Trichosurus vulpecula* and *Vombatus ursinus* labelled as coming from Deal Island and donated by J. A. Kershaw in 1909 and Stephenson in 1903.

Further subfossil remains have now been recovered from the valley at Winter Cove on Deal Island, and are listed in Table 2. Of these only *Macropus rufogriseus* and *Trichosurus vulpecula* are certainly still present on the island. The status of *Rattus lutreolus* and *Antechinus minimus* is unknown, but these two may still be present and the remainder are definitely extinct on Deal Island. However, it is likely that *Thylogale billardieri* at least was still alive at the time of European settlement of the islands, as G. A. Robinson in 1831 recorded both 'wallaby' (*T. billardieri*) and 'kangaroo' (*M. rufogriseus*) on Deal (Plomley 1966).

The valley is an erosion gully in a stabilized and partly consolidated sand dune. The actively eroding head of the gully is about 90 m above sea level, and the gully runs about 330 m downhill, parallel to the beach at Winter Cove at this point, then joins at right-angles a creek emptying into Winter Cove. Le Souef (1891) estimated that the gully extended about 200 yds down to the beach, so even allowing for some error in his estimate, the gully has probably grown in the last 75 years. At the head of the gully the walls are sheer, and here about 2 m of sandy soil overlies cross-bedded aeolian sands. Bones of *Puffinus tenuirostris*, *Macropus rufogriseus*, *Rattus lutreolus* and *Antechinus minimus* were collected from the walls of the gully. The bird bones and also eggshells were the most common. Bones protruding from these upper walls were rare and widely scattered, but lower down the hill, where the sides of the

gully are less steep and are vegetated, bones were found concentrated in pockets on the floor of the gully, undoubtedly washed down from above. The only remains of *Potorous apicalis* found were recovered from here.

A small sand blow exists on Erith Island and from this have been collected the bones of *Macropus rufogriseus*, *Thylogale billardieri*, *Trichosurus vulpecula*, *Rattus lutreolus* and *Oryctolagus cuniculus*. As well as occurring loose in the sand, bones have also been found cemented in calcarenite, a piece of which containing embedded bird bones was collected from Erith Island in 1965 by R. Truscott, and is now held in the National Museum of Victoria.

From a small sand blow on Hogan Island, 35 km NW. of Deal Island, the bones of *Rattus lutreolus* and the muttonbird, *Puffinus tenuirostris* have been collected.

AGE AND SIGNIFICANCE OF THE SUBFOSSILS

All the subfossil material at Palana was found either on top of the limestone layer, which in places extends inland as a flat platform, or in sand on the shoreward side of the dunes, in positions that could be accounted for by wind action. Deposits in unconsolidated sands from all islands seem to fit in with this. If so this material is postglacial in age. The species found embedded in limestone on some islands may date back to the last glacial period of the Pleistocene; the two species so found on King Island are in fact now extinct throughout Australia and are known only from Pleistocene and early postglacial deposits. The remains found in the loose sands may be quite old, however; dune midden deposits on the Victorian coast, which include marsupial bones, have been dated back to 6,000 years BP (Coutts 1967, Gill 1967). On the other hand at least some of the material is very new, for example the remains of introduced sheep and cattle, and the occasional skeleton of an obviously recently dead animal. It has been impossible to distinguish between older and more recent bones, as fragility of the bones seems only to indicate the degree of exposure to weathering. Exposed bones of introduced species in some cases were found to be more brittle and weathered than bones of species now absent or rare.

Why did so many bones accumulate in these dunes? Campbell (1888), who accompanied the Field Naturalists' expedition to King Island and visited the sand blow at Seal Bay, suggested that the animals were driven out on to the dunes by fire and perished there. Spencer and Kershaw (1910a) considered that this area had been one

of the most fertile on the island, before the introduction of sheep, and that it had consequently been a feeding ground for large numbers of animals. The sand dunes at Palana are certainly frequented by large numbers of marsupials today, judging by the numerous runs through both the vegetated and blowing dunes, and the many water holes scratched out just above the high tide mark.

It is possible that local catastrophes may have caused the death of a large number of animals at particular times. The large numbers of skulls of *Thylogale billardieri* and *Macropus rufogriseus* collected from the sand dunes on King Island may be due to the slaughter of these species during the early years of the 19th century, when thousands of these animals were killed on the islands. Several of the skulls of *Thylogale billardieri* in the National Museum of Victoria collection of subfossil material from King Island have been cut in half sagittally or have the back of the skull removed. Others show small round holes consistent with damage caused by shot pellets. These may be animals killed by sealers. However this still does not explain the presence in these deposits of smaller species which were not hunted.

Bones of the muttonbird, *Puffinus tenuirostris*, are particularly common in the sand blows of the islands, and it is possible that many of the blows have been initiated by the burrowing of these birds. Bones of birds and rodents are common in the disturbed sand around present day rookeries. It is possible that the dune at Palana at one time maintained a muttonbird rookery although none is there now. Only one small rookery, at Settlement Point, is known to exist on Flinders Island, while the large rookeries in the Furneaux Group are found on the smaller islands, notably Green, Babel, Great Dog and Mt Chappell Islands. In contrast, King Island, which has only three small islets nearby, supports several large rookeries along its coasts.

Whatever the reason for the deaths of so many animals in these areas, the calcareous dunes have obviously provided an ideal environment for the preservation of bone. It is probable that the accumulation of animal remains has continued from the very start of the formation of the dunes. The apparent abundance of subfossils in some blows, particularly those at Palana and on King Island, may be due merely to the accumulation of bones originally scattered sparsely through a sand dune. As the wind blows the sand into parabolic dunes, the heavy bones will tend to stay in place and accumulate on the floor of the blowout. Thus bones of different ages tend to be brought together.

DISTRIBUTIONAL DATA FOR THE MAMMALS

SOURCES

The following information on the distribution of mammals on the Bass Strait islands has been derived from several sources. Records for many islands are available in the journals of early explorers such as Flinders (1801, 1814) and Péron & Freycinet (1807-1816). Scott (1828) recorded information from James Campbell, boatman, on the islands and their fauna. Another important early source is the journals of George Augustus Robinson who travelled extensively in Bass Strait between 1830 and 1835, and who was responsible for the establishment of the settlement of Tasmanian Aborigines on Flinders Island in the 1830's (Plomley 1966). Towards the end of the 19th century the Field Naturalists' Club of Victoria held expeditions to King Island (Campbell 1888), the Kent Group (Le Souef 1891) and the Furneaux Group (Gabriel 1894). As the emphasis of these expeditions was on the avifauna of the islands, few records of mammals were made. At about the same time, several naturalists, including Atkinson (1890) and Ashworth and Le Souef (1895), visited the islands of the Hunter Group. In November-December 1908 the Australian Ornithologists' Union organized an expedition to the islands of Bass Strait (White 1909), and this was followed by an expedition to the eastern islands in January 1909 (Barrett 1918). Further notes on the mammal fauna of the islands have been made by Le Souef (1929), Green (1969), Green and McGarvie (1971) and Whinray (1971).

Between 1965 and 1968 I visited 11 of the 35 islands larger than 0.8 sq km in Bass Strait; these included all the major islands except those of the Hunter Group. Trapping for smaller mammals was carried out on Flinders, King, Cape Barren, Clarke, Deal and Hogan Islands. All material collected during this study has been housed in the collections of the National Museum of Victoria, and specimens referred to are from these collections unless prefixed by abbreviations of other institutions. These are as follow:

AM Australian Museum, Sydney
QVM Queen Victoria Museum, Launceston
SAM South Australian Museum, Adelaide

SYSTEMATIC ACCOUNT OF THE MAMMALS

A list of the mammals of Tasmania and the islands of Bass Strait is given in Table 3. Both living and extinct species, native and feral, are included, though some exotic species have been excluded, where they are apparently no longer

TABLE 3
MAMMALS OF TASMANIA AND THE ISLANDS OF BASS STRAIT

+ Extant
N Present until at least 1800; no recent records
F Fossil record only

I Introduced
V Visitor
— No record

| SPECIES | Aust. | Furn. Gp. | King I. | Tas. | SPECIES | Aust. | Furn. Gp. | King I. | Tas. |
|---------------------------------|-------|--------------|------------|------|----------------------------------|-------|--------------|------------|------|
| ORNITHORHYNCHIDAE | | | | | MACROPODIDAE | | | | |
| <i>Ornithorhynchus anatinus</i> | + | - | + | + | <i>Aepyprymnus rufescens</i> | + | F | - | - |
| TACHYGLOSSIDAE | | | | | <i>Bettongia gaimardi</i> | N | - | - | + |
| <i>Tachyglossus aculeatus</i> | + | + | + | + | <i>Potorous apicalis</i> | + | + | + | + |
| <i>Zaglossus harrissoni</i> | - | - | F | - | <i>Thylogale billardieri</i> | N | + | + | + |
| DASYURIDAE | | | | | <i>Macropus rufogriseus</i> | + | + | + | + |
| <i>Antechinus minimus</i> | + | + | + | + | <i>Macropus giganteus</i> | + | F | - | + |
| <i>Antechinus swainsonii</i> | + | - | - | + | <i>Macropus titan</i> | F | - | - | F |
| <i>Sminthopsis leucopus</i> | + | + | - | + | <i>Protemnodon anak</i> | F | - | F | F |
| <i>Dasyurus viverrinus</i> | + | F | - | + | <i>Sthenurus occidentalis</i> | F | - | F | F |
| <i>Dasyurus maculatus</i> | + | N | N | + | PTEROPODIDAE | | | | |
| <i>Sarcophilus harrisi</i> | F | F | - | + | <i>Pteropus poliocephalus</i> | + | V | V | V |
| THYLACINIDAE | | | | | VESPERTILIONIDAE | | | | |
| <i>Thylacinus cynocephalus</i> | F | - | - | N | <i>Nyctophilus geoffroyi</i> | + | + | + | + |
| PERAMELIDAE | | | | | <i>Nyctophilus timoriensis</i> | + | - | - | + |
| <i>Isodon obesulus</i> | + | + | - | + | <i>Eptesicus pumilus</i> | + | + | - | + |
| <i>Perameles gunnii</i> | + | F | - | + | <i>Pipistrellus tasmaniensis</i> | + | - | - | + |
| VOMBATIDAE | | | | | <i>Chalinolobus gouldii</i> | + | - | - | + |
| <i>Vombatus ursinus</i> | + | + | N | + | <i>Chalinolobus morio</i> | + | - | - | + |
| <i>Phascogale sp.</i> | F | - | - | F | MURIDAE | | | | |
| BURRAMYIDAE | | | | | <i>Hydromys chrysogaster</i> | + | + | - | + |
| <i>Cercartetus nanus</i> | + | + | + | + | <i>Rattus lutreolus</i> | + | + | + | + |
| <i>Cercartetus lepidus</i> | F | - | - | + | <i>Rattus rattus</i> | I | I | I | I |
| PETAURIDAE | | | | | <i>Rattus norvegicus</i> | I | - | - | I |
| <i>Petaurus breviceps</i> | + | - | - | I | <i>Mus musculus</i> | I | I | I | I |
| <i>Pseudocheirus peregrinus</i> | + | + | + | + | <i>Pseudomys higginsii</i> | F | F | F | + |
| PHALANGERIDAE | | | | | <i>Pseudomys novaehollandiae</i> | + | F | - | F |
| <i>Trichosurus vulpecula</i> | + | + | + | + | <i>Mastacomys fuscus</i> | + | F | - | + |
| THYLACOLEONTIDAE | | | | | FELIDAE | | | | |
| <i>Thylacoleo sp.</i> | F | - | - | F | <i>Felis catus</i> | I | I | I | I |
| DIPROTODONTIDAE | | | | | LEPORIDAE | | | | |
| <i>Palorchestes azael</i> | F | - | - | F | <i>Lepus europaeus</i> | I | I | - | I |
| <i>Nototherium sp.</i> | F | - | F | F | <i>Oryctolagus cuniculus</i> | I | I | - | I |
| <i>Zygomaturus trilobus</i> | F | - | F | F | SUIDAE | | | | |
| <i>Diprotodon optatum</i> | F | - | F | - | <i>Sus scrofa</i> | I | I | - | - |
| | | | | | CERVIDAE | | | | |
| | | | | | <i>Cervus dama</i> | I | - | - | I |

present on the islands in a feral state. A few Tasmanian species have not been recorded from the islands, but these are included for the sake of completeness. Marine mammals did not form part of this study.

The specific status of many populations of Australian mammals is uncertain, and the insular populations of Tasmania and the Bass Strait islands are particularly in need of study. Species names in this paper follow the taxonomy given by Ride (1970). Trinomials are not included in Table 3, but the subspecific status of the island populations is given in the following accounts.

ORNITHORHYNCHIDAE

Ornithorhynchus anatinus (Shaw and Nodder) 1799

Campbell (1888) recorded that one platypus was seen in the Etterick River, on King Island, by the Field Naturalists' Club expedition to the island. Green and McGarvie (1971) note that some are still known to occur there, mostly on the eastern side. Alliston (1966 p. 109) recorded seeing one on Three Hummock Island in the Hunter Group. No other records or museum specimens from Bass Strait are known to exist.

TACHYGLOSSIDAE

Tachyglossus aculeatus (Shaw and Nodder) 1792

The echidna, recorded on Flinders Island by Le Souef (1929), is still fairly common there. It occurs there in several colour varieties, ranging from cream to brown. Péron & Freycinet (1807-16) recorded the echidna on King Island in 1802. Campbell (1888) noted that it was plentiful on King Island in 1887, and that the Field Naturalists' expedition collected several specimens. Green and McGarvie (1971) say that it is still present on the island. Flinders (1814 p. exxxv) recorded that the echidna was seen on Cape Barren Island, but not on any other of the Furneaux Group that he visited. It is still present on Cape Barren I.; I saw one on the E. coast, near Harleys Point, in December 1966. It has not been recorded from any of the smaller islands, nor from the Kent or Hunter Groups. The island echidnas are the Tasmanian subspecies, *T. aculeatus setosus* (Geoffroy).
SPECIMENS: Flinders I.: C5607-10. King I.: C5621.

Zaglossus harrissoni (Scott and Lord) 1922

This extinct species of *Zaglossus* has been recorded only from King Island, associated with other elements of the Pleistocene fauna there (Scott & Lord 1922b, 1924c). Living members of the genus are restricted to New Guinea, and fossils referable to it have been recorded on the Australian mainland (Merrilees 1968) but not in Tasmania.
SPECIMEN: King I.: Holotype (left femur) QVM 1965/39/5.

DASYURIDAE

Antechinus minimus (Geoffroy) 1803

Antechinus minimus minimus is found in Tasmania

and on the Bass Strait islands, while *A. m. maritimus* is restricted to coastal areas of southern Victoria (Wakefield & Warneke 1963). The species has been recorded from Flinders I. (Green 1969), and Pegarah, King I. (Green & McGarvie 1971). Le Souef (1929) recorded a specimen from Clarke I. and the British Museum holds a specimen from Hummock I. (an early name for Prime Seal I.) (Thomas 1888). Hobbs (1971) records *A. m. maritimus* on Great Glennie Island. Alliston (1966 p. 96) has recorded 'marsupial mice' on Three Hummock Island. Wakefield and Warneke (1963) consider that the type specimen of *A. minimus*, collected by the Baudin expedition (Péron & Freycinet 1807: p. 359), came from Waterhouse Island, which lies close to the north-eastern coast of Tasmania. During this study, material referable to this species was found at Ranga Cave, Flinders I., and in the sand dunes of Deal and Preservation Islands.

SPECIMENS: Flinders I.: QVM 1961/1/12, 1967/1/52. King I.: C1925, C1926. Clarke I.: AM M4342. Deal I.: P 28007. Great Glennie I.: C9541.

Sminthopsis leucopus (Gray) 1842

Le Souef (1929) recorded this species from Clarke I. He also obtained a specimen from West Sister I. but incorrectly identified it as *Antechinus flavipes*. Green (1969) notes that the Australian Museum holds a third specimen collected by Le Souef on West Sister Island. Whinray (1972) notes that the species is still present on West Sister and that it has been introduced to East Sister Island. *Sminthopsis leucopus* is possibly more widely spread on the island and some of the small dasyurid material from Ranga Cave may belong to it.

SPECIMENS: Clarke I.: AM M4343. West Sister I.: C9566, AM M4459, M4584, SAM M2879.

Dasyurus viverrinus (Shaw) 1800

Le Souef (1929) stated that 'a Native Cat (*Dasyurus viverrinus*)' was 'reported as still being seen occasionally on Flinders and Barren Islands.' Since there have been no other records of its presence on any of the Bass Strait islands, it is possible that the animals seen on these two islands were in fact the tiger cat, *Dasyurus maculatus*. Campbell (1888) noted that the native cat was apparently absent from King Island. The species has been found in Ranga Cave, Flinders Island, but not in any of the island sand dunes.

SPECIMENS: Ranga Cave, Flinders I.: P27997-9.

Dasyurus maculatus (Kerr) 1792

The tiger cat was recorded on King I. by Campbell (1888), and was last seen there in 1923 according to Courtney (1963). Green and McGarvie (1971) discuss its decline on the island. Gabriel (1894) included it in a list of mammals seen in the Furneaux Group in November 1893, but there are no more recent reports of it from these islands and it may have died out. It is not represented in Ranga Cave, but has been collected from the sand dune deposits of King I., Flinders I. and has also been

collected from a limestone deposit on Cape Barren I. (E. Guiler, pers. comm.).

Spencer and Kershaw (1910a) described a larger species, *Dasyurus bowlingi*, from the sand dunes of King I., from where they also recorded *Dasyurus maculatus*. Marshall and Hope (1973) consider that only the one species is represented. *D. maculatus*, and that the difference in size between the two groups of skulls studied by Spencer and Kershaw is due to sexual dimorphism. Spencer and Kershaw also recorded a large dasyurid jaw from the sand dunes of Deal I., which they suggested might also be referable to *D. bowlingi*. This specimen is now apparently untraceable.

SPECIMENS: Palana, Flinders I.: P28004-5. King I.: C6139; QVM 1940/1/63, 1943/1/50; 1967/1/59; *D. bowlingi*, holotype, P15101, paratypes, P15102, P15111-2, P25940.

Sarcophilus harrisii (Boitard) 1841

The Tasmanian devil has not been recorded alive from any island in Bass Strait. It is represented in the Palana sand dune material by three mandibles which were associated with the remains of species still extant on Flinders Island. Although it has not been found in Ranga Cave, Flinders I., the fragmented condition of the bone there suggests that the Tasmanian devil may have been responsible for part of the deposit.

SPECIMENS: Palana, Flinders I.: P26779-81.

PERAMELIDAE

Isoodon obesulus (Shaw and Nodder) 1797

The brown bandicoot is still extant only on West Sister Island. It was recorded from there by Le Souef (1929) and Whinray (1972) has also commented on the population. Backhouse (1843 p. 85) wrote that he had seen a bandicoot caught by dogs near Blue Rocks, Flinders I., in 1832. This was probably *Isoodon*, as subfossil bones of the species have been recovered from the sand dunes at Palana, Flinders I. Green (1969) noted that J. A. Kershaw mentioned seeing signs of bandicoots on Flinders I. in 1909, but suggested that these diggings had probably been made by echidnas.

There are no records of the species alive elsewhere in Bass Strait, but it has been found as a subfossil on Cape Barren and Passage Islands. It is not represented in Ranga Cave.

SPECIMENS: Palana, Flinders I.: P28006. Cape Barren I.: P28020. Passage I.: P28025. West Sister I.: C7262-68, SAM M2886-91, AM M4451-52. Three Hummock I.: P30899.

Perameles gunnii (Gray) 1838

This species has not been recorded alive from the Bass Strait Islands, but is represented in the Ranga Cave deposit on Flinders Island.

SPECIMEN: Ranga Cave, Flinders I.: P27996.

VOMBATIDAE

Vombatus ursinus (Shaw) 1800

The wombat was first recorded in Australia from

Clarke Island in Bass Strait. Flinders (1814 p. cxxxv) recorded: 'Clarke's Island afforded the first specimen of the new animal, called *womat* (sic); but I found it more numerous upon that of Cape Barren; Preservation and the Passage Isles do not possess it'. Spencer and Kershaw (1910b) have described the discovery of the wombat on the islands and given an account of early descriptions of it. It was recorded on King I. in 1802 by Robert Brown (Willis & Skewes 1955), and a plate illustrating two wombats, with four young, with the locality given as 'ile King' appears in Lesueur and Petit's Atlas accompanying the account (Péron & Freycinet 1807-16) of the Baudin expedition. The log books of the *Lady Nelson* recorded wombats on Flinders Island in 1802 (Lee 1915 p. 91).

The Field Naturalists' found none on King Island during their visit of 1887 (Campbell 1888), but Spencer and Kershaw (1910a) recorded subfossils from King Island as well as from Deal Island. By 1910 wombats remained only on Flinders Island (Spencer & Kershaw (1910b), where they still persist. McLaren (1966) has described their present distribution on Flinders Island. Robinson (Plomley 1966 p. 270) recorded 'badger' on Woody Island but there are no other records of the species there. Neither is there any record of wombats on Badger Island, though the name suggests that they may have originally been there. During this study subfossils were collected from Flinders, Cape Barren and Deal Islands.

Vombatus ursinus was described on a specimen collected from the Furneaux Group, possibly Clarke Island. The mainland wombat has been described as a distinct species, *V. hirsutus* (Perry) 1810, but Ride (1970) considers all the southeastern Australian wombats to be a single species. Spencer and Kershaw (1910b) separated the Tasmanian population from the island form at a subspecific level, calling the former *V. ursinus tasmaniensis*.

Scott (1915a) suggested that wombat humeri from a cave at Molc Creek, Tasmania, and from Ranga Cave, Flinders I., were attributable to *Phascolumys* (= *Lasiiorhinus*) *latifrons*, which occurs in Central Australia. This is probably a misidentification.

SPECIMENS: Flinders I.: C6629-52, C6672-79, C8113, C8333, C10135. King I.: P15103-110. Cape Barren I.: P28024. Deal I.: P28009.

PHASCOLARCTIDAE

Phascolarctos cinereus (Goldfuss) 1817

Alliston (1966 p. 109) commented that four adult koalas had been introduced to Three Hummock Island from Victoria, but that none had been seen again and that it was supposed that they had died.

BURRAMYIDAE

Cercartetus nanus (Desmarest) 1818

The pigmy possum is present on Flinders, King and possibly Cape Barren Islands. Green (1969) recorded that one was found in Launceston inside a bale of wool from Flinders Island, and noted that they are occasionally found in the decaying stumps

of grass trees. The National Museum of Victoria has a female and four young collected at Lady Barron, Flinders I. by J. Whinray in February 1969. Green and McGarvie (1971) noted that the pigmy possum was rare on King Island, but that it is occasionally found at Egg Lagoon. Whinray (1971a) suggested that 'possum mice' reportedly caught on Cape Barren Island in the 1950's were probably *Cercartetus nanus*. It has not been recorded from any fossil deposit on the islands.

SPECIMENS: Launceston (ex Flinders I.): QVM 1966/1/20. Lady Barron, Flinders I.: C9571. King I.: QVM 1968/1/33, 1968/1/36.

PETAURIDAE

Pseudocheirus peregrinus (Boddaert) 1785

The ringtail possum is still present on Flinders, King and Cape Barren Islands. Gabriel (1894) recorded it for the Furneaux Group, and Le Souef (1929) and Green (1969) recorded it on Flinders Island. Green and McGarvie (1971) noted that it was common about thirty years ago on King Island, but has since declined in numbers there. Whinray (1971a) recorded it on Cape Barren Island. Its remains have been collected from the sand dune deposits of these three islands, and from Ranga Cave, Flinders I.

The Tasmanian population has been regarded as a distinct species, *Pseudocheirus convolutor* Oken 1816 (Tate 1945), and the ringtails of Flinders Island were described as a subspecies, *P. convolutor bassianus* by Le Souef (1929), based mainly on a difference in coloration. Campbell (1888) noted that the ringtails on King Island 'seemed rather darker in colour than the Victorian variety.'

SPECIMENS: Flinders I.: *P. c. bassianus*, holotype, AM M4450, allotype, AM M4449. King I.: C800, C1938, C3940-41. Cape Barren I.: P28021.

PHALANGERIDAE

Trichosurus vulpecula (Kerr) 1792

The brushtail possum is common today on King (Green & McGarvie 1971) and Flinders Islands (Green 1969). It was introduced onto Prime Seal and East Sister Islands in the 1920's and was still present on both these islands in 1966 (Whinray 1971a). Mullett and Murray-Smith (1967) collected a mummified carcase on Erith Island, and recorded sight observations on Dover Island of a brown, furred mammal which they thought was probably a brushtail possum. I collected several specimens on Deal Island in 1966. The brushtail is also present on the islands of the Hunter Group (Guiler 1953), and Alliston (1966 p. 108) has recorded it on Three Hummock Island.

The populations of *T. vulpecula* on the islands are the Tasmanian subspecies *T. v. fuliginosus* Ogilby 1831. Only the grey colour phase is found on King and Flinders Islands (Pearson 1938, Guiler 1953, Green 1969, Green & McGarvie 1971), though the black colour phase, which is dominant in western

and southern Tasmania apparently occurs on Hunters Island (Guiler 1953). Le Souef (1929) noted that the possums on Flinders Island were 'similar to, but brighter in colour than, old males from Victoria, differing materially from the Tasmanian form.' Green (1969) noted that old 'reds' seemed to be more common in areas close to the coast on Flinders Island.

Many early records of the brushtail possum on the islands (e.g. Keble (1945), Campbell (1888) for King Island, Gabriel (1894) for Flinders Island, and Le Souef (1891) and Barrett (1944) for Deal Island) identified it as the mountain possum, *T. caninus*, which occurs in wet sclerophyll forest in south-eastern Australia, but not in Tasmania. This possum resembles the Tasmanian form of *vulpecula* in its large size, but is distinguished by its smaller and rounder ear. However, while *T. vulpecula* on the mainland tends to be arboreal in habit, in Tasmania and on the islands it resembles the mountain possum in behaviour, being more terrestrial in habit and feeding to a large extent on the ground. I have seen the possums grazing at night among *Thylogale billardieri* on Flinders Island and among *Macropus rufogriseus* on Deal Island. Wood Jones (1924) noted similar behaviour in *T. vulpecula* on Kangaroo Island, South Australia. In view of this behaviour it is surprising that this species has not been recovered from the sand dune deposits on Flinders or King Islands. It has been found as a subfossil on Passage Island (where it no longer survives), Deal, Erith and Dover Islands, and in Ranga Cave on Flinders Island. SPECIMENS: Flinders I.: C3771-76, C3833-45. King I.: C8029, C8771. Deal I.: C3831-2, 8048-9, 8051-2, 8055-6, 8731. Erith I.: C9482, P28030. Dover I.: P28016. Passage I.: P28027.

DIPROTODONTIDAE

Diprotodon optatum (Owen) 1838

This extinct species has been recorded from swamp deposits at Egg Lagoon, King Island (Keble 1945). It has not been recorded from Tasmania or elsewhere in Bass Strait.

SPECIMEN: King I.: P14403.

Nototherium sp.

Fossils from the swamp deposits at Egg Lagoon, King Island, were attributed to *N. victoriae* by Scott (1912, 1915a) and those from South-East Lagoon to *N. victoriae* and *N. mitchelli* (Scott & Lord 1921b, c, d, 1924a, b, c). Any genuine specimens of *Nototherium* should probably be referred to *N. inerme* (Woods 1968), but some of this material may in fact be *Zygomaturus trilobus*.

SPECIMEN: King I.: '*N. victoriae*' QVM 1965/39/3, collected by F. H. Stephenson 1912.

Zygomaturus trilobus (Owen) 1859

The type specimen of *Nototherium tasmanicum* Scott 1911, from Mowbray Swamp, northwest Tasmania, has been re-identified as *Zygomaturus trilobus* (M. Plane, pers. comm.), a species which was wide-

spread through southern Australia in the late Pleistocene.

SPECIMEN: Lovell's farm, Mowbray Swamp, Tasmania; *N. tasmanicum*, holotype, QVM 1965/39/2.

MACROPODIDAE

Aepyprymus rufescens (Gray) 1837

This species has been recovered from Ranga Cave, Flinders Island. A fragmented but almost complete skull was collected in the extension of the cave, and several teeth were found during the excavation of the floor deposit. It is not otherwise known from the modern or fossil faunas of Tasmania and the islands.

SPECIMEN: Ranga Cave, Flinders I.: P 26784.

Potorous apicalis (Gould) 1851

Potoroos are rare but still present on Flinders and King Islands. Le Souef (1929) recorded a specimen from Flinders Island, and in 1966 a decayed carcase was found at Blue Rocks. Several more have since been trapped nearby at Pats River by Mr D. Smith of Whitemark. On King Island they were reasonably common until about 1948, but have since declined in numbers (Courtney 1963). Green and McGarvie (1971) have given some more recent records for this island. Five specimens from Clarke Island were purchased by the National Museum of Victoria in 1923, but apparently none survive on that island now. When I visited Clarke Island in December 1966, the caretaker, Mr T. Higgins, said that he had trapped only rabbits and wallaby there. Whinray (1910a) noted that kangaroo rats were occasionally caught on Cape Barren Island before the Second World War. Atkinson (1890) recorded 'Rat Kangaroo' on Hunter, Robbins, Walker and Three Hummock Islands in the Hunter Group.

Potoroo remains have been recovered as subfossils from King Island (Spencer & Kershaw 1910a) and from Palana, Flinders Island, Cape Barren Island and Deal Island. They are also represented in the subfossil collections from Three Hummock Island held by the National Museum of Victoria.

Courtney (1963) described two specimens from King Island as a new subspecies, *P. tridactylus benormi*. Hope (1969) has studied the taxonomy of these and other populations on the islands, as well as in Tasmania and on the mainland. The King Island population does not differ from that in north-western Tasmania, but these two populations, as well as those from the Furneaux Group and Victoria are smaller than the potoroos from Eastern Tasmania. All, however, are similar morphologically, and distinct from *Potorous tridactylus* of New South Wales. SPECIMENS: Flinders I. Blue Rocks: C8285; Pats River: C8859; Lady Barron: AM M4398; Ranga Cave: P26786-7; Palana: sand dune: P26782. King I.: C6563-4; SAM M5757-8; *P. t. benormi*, holotype AM M8319, allotype AM M8373. Cape Barren I.: P28017-8. Clarke I.: C6759-60, C6164-6. Deal I. P28008. Three Hummock I.: P30900.

Thylogale billardieri (Desmarest) 1822

Macropus rufogriseus (Desmarest) 1817

These two species are dealt with together, because of the problems of determining which species is meant by literature records of 'wallaby' and 'kangaroo' in Bass Strait. The three large macropods found in Tasmania today, the grey kangaroo, *Macropus giganteus*; the brush wallaby, *Macropus rufogriseus*; and the Tasmanian pademelon, *Thylogale billardieri*, are colloquially referred to there as the forester (or boomer), the kangaroo and the wallaby, respectively. This usage is apparently very old, as G. A. Robinson, in his journals of 1830-35 (Plomley 1966), distinguished between forester kangaroo, bush or brush kangaroo and wallaby kangaroo. It is easy to determine which species is meant when the descriptions are as clear as this, but other writers have often used the word 'kangaroo' without any qualification. In general I have taken 'kangaroo' to refer to *M. rufogriseus*, and 'wallaby' to *T. billardieri* in literature records. Ambiguities often arise, as in Robinson's statement (Plomley 1966 p. 269): '... that Hunter Island at one time swarmed with kangaroo; the 11 months he was there he saw 4000 wallaby skins.' Fortunately, there are several reports for most islands, so ambiguous ones need not always be relied on.

The earliest records for the islands are those of Flinders (1801, 1814). He wrote (1801 p. 26): 'Kanguroos (sic) are found upon Preservation, Clarke's and Cape-Barren Islands of the smaller red kind; and the large grey kanguroos have been seen in considerable numbers upon the southern part of the largest island.' The latter island is probably Flinders Island, as Flinders never referred to it by that name, only as the 'large' or 'largest' island (*Ibid.* p. 25). It seems likely that the 'grey kanguroos' were *Macropus rufogriseus* (as there are no other records, except fossil ones, of the great grey kangaroo, *M. giganteus*, on the islands), and that the 'smaller red kind' was *T. billardieri*. However, Flinders later wrote (1814 p. cxxxiv): 'The kangaroo is of a reddish brown, and resembles the smaller species which frequents the brush woods at Port Jackson: when full grown it weighs from forty to fifty pounds. There were no traces of it upon the Passage Isles; but, upon Cape-Barren and Clarke's Islands, the kangaroo was tolerably abundant, though difficult to be procured, owing to the thickness of its retreats. There were also numbers on Preservation Island, when the Sydney Cove was first run on shore; but having been much harrassed and destroyed, a few only were shot during the time of our stay.' The size given is too large for *T. billardieri*, yet the colour is more suggestive of *T. billardieri* than of *M. rufogriseus*. Later, however, on King Island, Flinders commented (1814, p. 207): '... and a kangaroo; the last being of a middle size between the small species of the lesser islands, and the large kind found at Kangaroo Island and on the continent. It appeared indeed, all along the South Coast, that the size of the kangaroo bore some proportion to the extent of land which it inhabited.' This certainly suggests that the species

Flinders saw on the smaller islands was *T. billardieri* rather than *M. rufogriseus*. Presumably the 'middle size' kangaroo on King Island was *M. rufogriseus*. Flinders (1814 p. cxlviii) also noted that Swan I. was 'destitute of the kangaroo'.

In the Furneaux Group, 'kangaroo' were recorded on Flinders, Clarke, Badger and Guncarriage (Vansittart) Islands by Scott (1828). G. A. Robinson recorded in 1830 that Clarke Island 'at one time abounded in kangaroo' (Plomley 1966, p. 268), and that Long Island also 'at one time abounded with game.' (*Ibid.* p. 270). Gabriel (1894) included *Halmaturus Bennetti* (= *Macropus rufogriseus*) in a list of mammals noted at the Furneaux Group the previous year. Lord (1908) recorded that 'kangaroo' had died out on Vansittart Island during the 19th century, but had been reintroduced there about 1880 and had become numerous. 'Kangaroo' was also listed for Vansittart Island in Mr John Burgess' records (Ashby 1927), but it is no longer present on that island. Ashby (1927) also listed kangaroo on Flinders, [Cape] Barren and Babel Islands. Whinray (1971a) suggests that the species was introduced onto Babel Island in 1965; and that the present Badger Island population is also an introduced one. As well as these two islands, *Macropus rufogriseus* is still present on Flinders and Cape Barren Islands. In the Furneaux Group, subfossil remains of this species have been found on Flinders, Cape Barren and Preservation Islands, and also in Ranga Cave. A skull of *M. rufogriseus* in the NMV is labelled 'Hummock I., Bass Strait, Jan. '09', and was collected by J. A. Kershaw. Hummock (Prime Seal) Island was visited by Kershaw during the 1909 'New-Year Trip' to the Furneaux Group (Barratt, 1918, Vol. 2: 119-136). The only records of a living macropod on Preservation Island are Flinders' ambiguous comments. It is surprising that *M. rufogriseus* was found in the sand dunes there as this species has been recorded from no other small island. It may, however, have been reintroduced onto Preservation at some time, and have later died out.

Scott (1828) recorded 'wallaby' from the following islands in the 'Furneaux Group': Flinders, Clarke, Badger, Babel, Prime Seal, Long, Dog, Guncarriage and Little Kangaroo. Robinson recorded that 'wallaby kangaroo' were present on Cape Barren Island in 1831 (Plomley 1966 p. 224). Gabriel (1894) included *Halmaturus billardieri* (= *Thylogale billardieri*) in his list of mammals of the Furneaux Group. Ashby (1927) listed 'wallaby' from Flinders, [Cape] Barren, Clarke, Prime Seal, Babel and East and West Sisters Islands. There are further records of 'wallaby' on Babel (Gabriel 1894), on Badger (Brownrigg 1872) and on West Sister (Barrett 1909). Barrett (1918 Vol. 2 p. 126) commented that wallaby had not been known on Kangaroo Island during the 70 years previous to 1909, and that in 1909 there were 'numerous wallaby' on Hummock (Prime Seal) Island. *Thylogale billardieri* is still present on Flinders, Cape Barren, Clarke and Prime Seal Islands, as well as on East and West Sister (Whinray 1971a). Several from Flinders and Clarke Islands were collected during

this study. There is no record of any sort of the species from Mt. Chappell, Tinkettle, Forsyth or Woody Islands, although these are all larger than the smallest island from which species have been recorded. The species has been found subfossil in the sand dunes of Flinders, Cape Barren, Kangaroo and Passage Islands, and in Ranga Cave. Several skulls of *T. billardieri* in the NMV were collected by J. A. Kershaw on Hummock (Prime Seal) I. on 13.1.09.

Flinders (1814, p. cxliv, in footnote) recorded that on the Kent Group 'kangaroos of a small kind were rather numerous'. The log books of the *Lady Nelson* (Lee 1915 p. 96) recorded that in 1801 'two large and 3 small kangaroos' were caught on the Kent Group. Another note (*Ibid.* p. 98) states that three kangaroos were caught on 'the opposite or west side of the land from the cove we lay in.' This suggests that they were caught on Erith Island, as the only cove on that island is on the eastern coast, while the safest anchorage on Deal Island is on the west coast. Grimes (Shillinglaw 1879) also recorded 'a kangaroo' on the Kent Group. Robert Brown spent three weeks on the Kent Group in 1803, and his MS lists several species from there (J. H. Calaby pers. comm.). This reads 'Macropus melanopus Pattemelan Incol: abor: prope P. Jackson vulgaris in Insula orientale. Pondus 16-28 lib.'; 'Macropus Bettong Incol. . . frequens in utraque Insula P. Jackson Pondus 7-12 lib.'; 'Macropus Brush Rat Incol. Aug. P. Jackson umcus visus & occisus in Insula orientali'; 'Didelphis a small animal running on all fours indistinctly seen on the Eastern Island'. The eastern island is Deal, the western ones Erith and Dover.

Table 4 gives some comparative weights for various species on the Bass Strait islands. 'Macropus melanopus' is closest to the samples of *M. rufogriseus* in weight range, 'Macropus Bettong' to *T. billardieri*.

TABLE 4
COMPARATIVE BODY WEIGHTS OF SOME
BASS STRAIT AND TASMANIAN MAMMALS

| Species | Mean Kg | Range Kg | No. |
|---|---------|----------|-----|
| 'Macropus melanopus' Kent Group 1803 | — | 7.0-13 | — |
| 'Macropus Bettong' Kent Group 1803 | — | 3.0- 5.5 | — |
| <i>Macropus rufogriseus</i> Deal I., May-June 1966 | 12.4 | 3.5-21.5 | 9 |
| <i>Macropus rufogriseus</i> Flinders I. December 1965 | 12.7 | 5.0-24.7 | 9 |
| <i>Thylogale billardieri</i> Flinders I. December 1965 | 4.6 | 1.5-10.5 | 24 |
| <i>Potorous apicalis</i> (from Guiler 1961) | — | 0.6- 1.5 | — |
| <i>Potorous apicalis</i> NW. Tasmania 1966-67 | 0.9 | 0.8- 0.9 | 6 |
| <i>Trichosurus vulpecula</i> Deal I., May-June 1966 | 1.2 | 0.9- 1.8 | 5 |

Both *Potorous apicalis* (subfossil on Deal Island) and *Trichosurus vulpecula* (still extant there) are too small to account for 'Macropus Bettong'. This suggests that both *M. rufogriseus* and *T. billardieri* were on the Kent Group in 1803.

Oxley (1810 p. 775) wrote that in the Kent Group 'the islands are uninhabited, but the Vallies abound with Brush Kangaroo'. In 1831, Robinson noted both wallaby and kangaroo on Deal Island (Plomley 1966 p. 338). However, Stokes (1846, Vol. 2. p. 425) commented that the rabbits he had released there would probably soon overrun the islands, 'there being no wallabies to offer molestation,' and Le Souef (1891) did not mention either species on the islands. Barrett (1918, Vol. 2. p. 122) wrote that in 1909 there were some kangaroo on the island, and noted that he had promised to restock the island with 'wallaby' from 'a Toorak paddock'. I can find no record as to whether this was done. Ashby (1927) listed 'kangaroo' on Deal Island, and *Macropus rufogriseus* were observed and collected there during my visit in 1966. Whinray (1971b) supposed the species to have been introduced to the island.

Apart from Flinders (1814) record for King Island, 'kangaroo' were noted there in 1802 by Robert Brown (Willis & Skewes 1955) and by Grimes (Shillinglaw 1879). The log books of the *Lady Nelson* noted that in 1802 (Lee 1915 p. 120): '15 or 20 kangaroos from 30-40 pounds in weight' were seen on King Island. Stokes (1846 Vol. 1. p. 266) said 'there are three varieties of kangaroo on the island'. Campbell (1888) recorded both species there in 1887, and both are still plentiful (Green & McGarvie 1971). Their remains have been recovered from the sand dunes at Surprise Bay (Spencer & Kershaw 1910a).

Robinson recorded in 1830 that Hunter Island 'at one time abounded with kangaroo, but they are now very scarce' (Plomley 1966 p. 176). It seems that by 1832 *Macropus rufogriseus* was no longer on Hunter Island, as Robinson found it necessary to send sealers to the Welcome River, on the mainland, to procure 'kangaroo' for his party; although the aborigines were still hunting 'wallaby' on the island (*Ibid.* p. 635). Atkinson (1890) recorded only 'wallaby' from Hunter Island, and the most recent record I can find for this island is one of 'wallabies' in 1909 (Barrett 1939).

When Robinson visited Robbins Island in 1830, he wrote: 'It is in the recollection of several persons whom I have conversed with that this island was covered with kangaroo' (Plomley 1966 p. 178). Atkinson (1890) recorded both kangaroo and wallaby. Similarly Robinson recorded that kangaroo had once been common on Walker Island (*Ibid.* p. 178) and Stokes (1846 Vol. 1. p. 273) noted that 'the wives of some sealers' there depended for food on 'wallabi' (sic). Atkinson (1890) recorded both kangaroo and wallaby here. On Three Hummock Island, in the Hunter Group, 'some small kangaroo' were recorded in 1802, in the log books of the *Lady Nelson* (Lee 1915 p. 124). Robinson recorded in 1830 that kangaroos were rare on Three Hummock, and two

years later his Aborigines did not find any 'wallaby' there. However, he wrote that 'Parish informed me that he had been on the island for a long time and caught an abundance of wallaby' (*Ibid.* p. 670). Atkinson (1890) was puzzled by the absence of all mammals here except the rat-kangaroo, but Ashworth and Le Souef (1895) found numerous wallaby bones on the island, and commented that the extinction of the species there must have been very recent. A note associated with a collection of *T. billardieri* from Three Hummock Island, held by the Queen Victoria Museum, Launceston, states that the species was reintroduced onto the island in 1900 by John Burgess, the lessee at that time. This species is still present on Three Hummock Island (Alliston 1966).

Macropus rufogriseus was described on specimens collected on King Island (Iredale & Troughton 1934). The Tasmanian and Flinders Island populations have been described as a separate subspecies, *M. r. frutica* (Ogilby) 1838, and the mainland form as a further subspecies, *M. r. banksiana* (Quoy and Gaimard) 1825. Calaby (1971) considers the Tasmanian and island populations to be a distinct subspecies from that on the mainland. No subspecies of *Thylogale billardieri* have been described, but the populations on the various islands vary considerably in tooth and skull size.

SPECIMENS: *Thylogale billardieri*: Flinders I.: C6013-35, C7998-8005. King I.: C7906-07, P24515-34, P24552-6. Cape Barren I.: P28022-23. Prime Seal I.: C6000-12, C6966-68, P24510-14. West Sister I.: C7838-47, C7996-98, C8062-74. East Sister I.: AM M4782-3. Clarke I.: C8006, 8010, 8025. Passage I.: P28028. Deal I.: P28012. Erith I.: P28039. Kangaroo I.: P24535-6. Three Hummock I.: QVM 1961/1/29; P30901-2.

Macropus rufogriseus: Flinders I.: C6537-52, C8034-41. King I.: C1939-44, C7905, C8033. Cape Barren I.: C7852-3, C8835-43. Preservation I.: P28015. Deal I.: C8042-47, 8053-4, 9191-2. Erith I.: P28031, P30903.

Macropus giganteus (Shaw) 1790

The grey kangaroo has not been recorded alive from the islands of Bass Strait, but was recorded as a subfossil from Deal Island by Le Souef (1891). This specimen is now untraceable. Several teeth referable to *M. giganteus* have been recovered from Ranga Cave, Flinders I.

SPECIMEN: Flinders I. Ranga Cave.: P27995.

Protemnodon anak (Owen) 1859

This species has been recorded, as '*Macropus anak*', fossil on King Island, from both the swamp deposits at South-East Lagoon (Scott & Lord 1924e) and from calcarenites at Surprise Bay (Scott 1905). This material was not examined during this study. The NMV holds specimens of skull and mandible fragments of this species, which are probably part of the collection reported by Keble (1945).

SPECIMEN: King I.: P30786.

***Sthenurus occidentalis* (Glauert) 1910**

Several fossil specimens collected from the calcarenites at Surprise Bay, King Island, were identified first as *Procoptodon rapha* (Scott 1906) and later as *Sthenurus atlas* (Scott 1917). These are in fact referable to *Sthenurus* (*Simosthenurus*) *occidentalis* (Anderson 1932; Telford 1966).

SPECIMENS: King I.: QMV 1971/39/1 (skull), 1971/39/2 (right mandible), 1971/39/3 (premolar and molar removed from skull).

MURIDAE***Hydromys chrysogaster* (Geoffroy) 1804**

This species was recorded from Flinders Island by Le Souef (1929) and is still present there (Green 1969; Whinray 1971a). Whinray (1971a) noted that the water rat was most recently seen on West Sister I. about 1960, was noted on Prime Seal Island during the 1920's and 1930's and has been seen recently on Cat Island. The South Australian Museum has a specimen collected on West Sister Island in 1929 or 1930. The species is also recorded for Three Hummock Island (Alliston 1966, p. 97). The water rat is probably present on many of the islands with permanent rivers or creeks.

SPECIMENS: Flinders I.: C4847. West Sister I.: SAM M2892.

***Rattus fuscipes* (Waterhouse) 1839**

The bush rat has been recorded in Bass Strait only from Great Glennie Island off Wilsons Promontory. Hobbs (1971) has studied the population there, which is slightly larger in skull size than populations of the species in Victoria.

SPECIMEN: Great Glennie I.: C9068.

***Rattus lutreolus* (Gray) 1841**

The swamp rat has been collected alive on Flinders, King, Cape Barren and Hogan Islands. It has been recorded as a sub-fossil from the sand dunes of Flinders, Cape Barren, Passage, Preservation, Deal and Erith Islands, and from Long Island in the Hogan Group. It may be still extant on some of these islands and on others as well.

'Rats', 'bush rats' or '*Mus* sp.' were recorded from many islands by early visitors to Bass Strait (e.g. Campbell 1888; Gabriel 1894). It is difficult in most cases to determine which species is meant. G. A. Robinson recorded 'rats' on Deal, Clarke, Woody and Swan Islands in 1830-35, and commented on their numbers and habits on Swan I. (Plomley 1966, p. 353): 'Nor should I omit to mention the numerous rats which infest this and all other islands, as these destructive animals make regular nocturnal visits to the stores and to every part of the encampment'.

The evidence for *R. lutreolus* invading human habitation is indefinite; Green (1967) quoted a report of this species invading camps of duck-shooters, but on the other hand he found that it rarely invaded walking huts in Tasmania. It is possible that the rats that plagued Robinson were *R. rattus* since there were already several hundred scalers living on the

islands by 1830. Yet *R. rattus* is now found on very few islands in the Strait.

On Flinders Island *R. lutreolus* was trapped in a dense stand of *Melaleuca squarrosa* in Smith's Gully in 1966-7. Green (1969) has also collected it at Memana and Locotta. On King Island the species was taken amongst *Melaleuca ericifolia* and *Acacia melanoxylon* at the Nook, a swampy interdune area on the NE. coast. Green and MacGarvie (1971) also record several specimens from King Island. Whinray (1971a) has collected a specimen on Mt Munro, Cape Barren Island. On Hogan Island, several specimens were trapped in January 1968, amongst outcrops of calcarenite about 5 m from the shore. Here the vegetation consisted of an open shoreline community of low herbs and grasses on loose calcareous sands.

Green (1969) and Green and MacGarvie (1971) noted that the specimens they collected on King and Flinders Island belonged to the Tasmanian subspecies, *R. lutreolus velutinus* (Thomas) 1882. The specimens from Hogan Island also belong to this subspecies (Wakefield 1969).

SPECIMENS: Flinders I., Smiths Gully: C8324, C9465, Memana: QVM 1967/1/39-40. King I. The Nook: C8320, C8328. Locotta: QVM 1967/1/53, 1967/1/55. Cape Barren I. Mt. Munro: C9635, Cape Barren sand dune: P28019. Deal I.: P28010. Erith I.: P28011. Preservation I.: P28013. Passage I.: P28026. Hogan I.: C8325-27, C8814-17, C8846. Long I. (Hogan Gp.): P28014.

***Rattus rattus* (Linnaeus) 1758**

On Flinders Island the introduced ship rat was trapped at Smith Gully in December 1966-January 1967 in the same tea-tree swamp as *R. lutreolus*. It was also trapped at Palana. Green (1969) also collected the species at Smiths Gully and at Lackrana. The rat is abundant throughout the muttonbird rookery on Big Green Island (Norman 1966), and Whinray (1971a) has trapped it at Mt Munro, Cape Barren Island. He also records one found dead in a mutton-birding shed on Great Dog Island in 1967. I trapped several on Deal Island in May-June 1966. Green and MacGarvie (1971) record three collected at Pegarah, King Island.

SPECIMENS: Flinders I.: C8695-6, QVM 1966/1/15, 1967/1/41. King I. Pegarah: QVM 1968/1/8-10. Big Green I.: C7764-65.

***Mus musculus* (Linnaeus) 1758**

The introduced house mouse is common on both Flinders Island (Green 1969) and King Island (Green & MacGarvie 1971). Campbell (1888) reported that 'imported mice' were very numerous on King Island in 1887. Whinray (1971a) has recorded the species from Flinders, Cape Barren, Babel, East Kangaroo, Great Dog, Little Dog, Badger and East Sister Islands. He notes that it was present on Prime Seal Island in the 1920's and 1930's.

SPECIMENS: Babel I.: C7791-93.

***Pseudomys novaehollandiae* (Waterhouse) 1843**

Several skull fragments and lower jaws recovered

from Ranga Cave on Flinders Island may be referable to this species. The only record of the New Holland mouse in Tasmania is from a cave deposit at Flowery Gully (Green 1967; Gill 1969).

***Pseudomys higginsii* (Trouessart) 1899**

The long-tailed rat has not been recorded alive from any of the Bass Strait islands, but it has been found in the sand dune deposits on King Island and in Ranga Cave, Flinders I.

The species is endemic to Tasmania, but has recently been found as a fossil in cave deposits in Victoria and New South Wales (Wakefield 1972).

SPECIMENS: King I.: P28001. Ranga Cave, Flinders I.: P30898.

***Mastacomys fuscus* (Thomas) 1882**

This species has been recovered from the bone deposit at Ranga Cave, Flinders Island. Calaby and Wimbush (1964) give the locality of a specimen collected by Brazenor (1934) as Swan Island, Bass Strait. However, this specimen (C200) is in fact from the Swan Island in Port Phillip Bay, since the museum label gives its locality as 'Swan I. nr Queenscliffe'. There are apparently no other records of *M. fuscus* from Bass Strait.

SPECIMEN: Ranga Cave, Flinders I.: P28000.

PTEROPODIDAE

***Pteropus poliocephalus* (Temminck) 1825**

A grey-headed fruit bat was found in a shed on Babel Island in 1955 (Sharland 1962) and a further specimen was captured on Great Dog Island in 1958 (Green 1969). Green and McGarvie (1971) recorded two similar occurrences on King Island.

VESPERTILIONIDAE

***Nyctophilus geoffroyi* (Leach) 1821**

The lesser long-eared bat has been reported from both King and Flinders Islands (Green 1966) and one has also been collected in an old house on West Sister Island (Green 1969).

SPECIMENS: Flinders I. Whitemark: QVM 1968/1/19. King I.: QVM 1968/1/50. West Sister I.: QVM 1968/1/28.

***Eptesicus pumilus* (Gray) 1841**

One specimen of the little brown bat was collected at Emita, Flinders Island in 1947 (Green 1969).

SPECIMEN: Flinders I.: QVM 1959/1/4.

FELIDAE

***Felis catus* (Linnaeus) 1785**

Feral cats are present on Flinders Island (Green 1969) and King Island (Green & McGarvie 1971). Whinray (1971a) recorded them for Cape Barren, Clarke, Babel, East Sister, Little Green, Great Dog, Little Dog and Mt Chappell Islands, and reports that they were very common on Prime Seal Island in the 1920's and 1930's. They were noted on Deal Island in 1890 (Le Souef 1891) and on King Island in 1887 (Campbell 1888). Barrett (1918 Vol. 2 p.

138) noted 'imported cats' on Ninth Island in 1909. Alliston (1966 p. 109) has recorded wild cats on Three Hummock Island.

CANIDAE

***Canis familiaris* (Linnaeus) 1785**

Although there are no reports of feral dogs still present on most of the islands, it is clear from early reports that they were common there during the last century. The dogs originally belonged to the Aboriginal women living with the sealers and were used to hunt kangaroo and wallaby, but inevitably many went wild. G. A. Robinson commented on the number of dogs on the islands between 1830 and 1835. He wrote that on Guncarriage Island (Plomley 1966 p. 272): 'It was a singular sight to see the women return from the bird rookery with their numerous dogs, most of them of a very large kind. I counted upwards of forty and was told that there was fifty dogs then on this island and at Woody there was ten, besides the herd of dogs the women have taken with them to Flinders. I suppose there cannot be less than two hundred dogs in these straits, all of a very large description. Most of these islands are infested with wild dogs'. Robinson also recorded wild dogs on Great Dog and Little Dog Islands, and on Swan Island 'thirty large and fierce dogs belonging to the natives' (*Ibid.*: 374). In 1908 Lord reported that there were less wild dogs on Flinders at that time than for many years. Alliston (1966 p. 109) suggests that feral dogs may still be present on Three Hummock Island.

LEPORIDAE

***Oryctolagus cuniculus* (Linnaeus) 1785**

Rabbits are common on Clarke Island, where they were introduced about 1923, according to Whinray (1971a). Stokes (1846. Vol. 2 p. 424) released about a dozen rabbits on Deal Island in 1842. Le Souef (1891) commented that in November 1890, rabbits were numerous on Erith Island, where there were no 'half wild domestic cats to destroy them like there are on Deal Island'. J. A. Kershaw recorded rabbits on Erith Island in 1909 (Green 1969), but there are no more recent records of them there, though skulls have been collected from a sand blow on that island. In 1966 the lightkeeper told me that rabbits were still occasionally seen on Deal Island.

Stokes (*Ibid.* p. 426) also commented that a sealer had released a pair of rabbits on Rabbit Island about six years before his visit in 1842; by then they were abundant. Barrett (1918. Vol. 2 p. 115, 121) recorded that they were still on Rabbit Island, but Norman (1971) says that they seem to have been eliminated by myxomatosis and '1080' poisoning.

Rabbits were recorded on Big Green Island by Thomas (1861), but H.S. (1883) wrote that: 'In five years eight thousand rabbits . . . were killed, but now there is not a rabbit to be seen'. There are no rabbits on Big Green now. Rabbit bones have been collected from a sand blow on nearby Kangaroo Island. There seem to be no rabbits on Flinders Island at present, and Green (1969) has described the

attempts made to eradicate the few that have been seen there over the last 20 years.

There are no records of rabbits on King Island or the Hunter Group.

Lepus europaeus (Pallas) 1778

The introduced hare is present only on West Sister Island. They were recorded there by Barrett (1909), and have apparently been there for at least 60 years (Whinray 1972).

BOVIDAE

Cattle, Sheep and Goats

The smaller islands especially have had a long history of grazing, and many are still leased for this purpose. Apart from domestic sheep and cattle, goats were released onto many islands during the last century. Le Souef (1891) recorded that one was present on Erith Island in 1890, and Barrett (1909) recorded them on West Sister Island. They were liberated on Seal Island off Wilsons Promontory in 1884 to provide emergency food for the light keepers on nearby Clifty Island (Victorian Department of Public Works 1970). Bones of cattle and sheep or goats have been found in the sand dunes of many islands.

SUIDAE

Sus scrofa (Linnaeus) 1785

Wild pigs are fairly common on Flinders Island, particularly in the Strzelecki Ranges. They were observed in Smiths Gully in December 1965 and December 1966. Pullar (1953), in a study of feral pigs in Australia, suggested that those on Flinders Island were derived from domestic pigs placed on the island by sealers to breed at will and augment the food supply. Stokes (1846, Vol 2, p. 445) noted that pigs had been liberated on to Swan Island.

THE DEVELOPMENT OF THE MAMMALIAN FAUNA OF THE ISLANDS

Using the fossil record of the islands and the modern historical reports, the mammalian fauna on the Bassian land bridge at the end of the Pleistocene can be reconstructed, and its development traced through its subsequent isolation on the islands, until the present day.

In the Late Pleistocene there was, at least on the western side of the Bassian peninsula, a mammal fauna, containing both extinct and modern species, similar to that present over wide areas of Australia at the time. Only one of the extinct Pleistocene species (*Zaglossus harrissoni*) may have been restricted to this region; the remainder were common species throughout southern Australia. However, all of the modern species associated with the Pleistocene ones are Tasmanian. It is not known how long the extinct species survived on the peninsula, but they are not found in any of the Aboriginal middens in Tasmania which

date back to 8,500 years BP (Jones 1968) nor at Flowery Gully Cave (Gill 1968) or Ranga Cave which are both about the same age. The calcarenites on King Island containing *Sthenurus occidentalis* and *Protemnodon anak* are undated but probably consolidated during the last glacial period. On the mainland the extinct marsupials do not seem to have survived later than the end of the last glaciation.

Merrilees (1968) and Jones (1968) have discussed the Australia-wide extinction of the giant species of the Pleistocene fauna and suggest that their disappearance was due to environmental modifications due to man-made fires, rather than to climatic change as has often been suggested. There is certainly evidence that the Tasmanian vegetation has been modified by fires set by Aboriginal man (Jackson 1965), but these fires usually resulted in increasing areas of grassland and sedge-land, which would perhaps have been more congenial than the natural climax forest to the extinct species. An increase in aridity, which has been suggested as a cause for the extinction of the Pleistocene fauna, would in Tasmania have had a similar effect in providing more open country.

Although it is generally believed that Aboriginal man reached Tasmania by way of the Pleistocene land bridge (Jones 1968), the major islands of Bass Strait were found to be completely uninhabited by man when Europeans first visited them. Only the islands of the Hunter Group, close to the Tasmanian coast, were inhabited, or at least regularly visited by the Tasmanian Aborigines (Meston 1936). Jones (1968) has suggested that during late glacial times the economy of the Tasmanian Aborigines was exclusively marine, so any archaeological sites of this time would have been strictly coastal and would have been drowned postglacially by rising sea level. However if Aborigines were living even along the coasts of the glacial Bassian peninsula, they may have had some influence on the mammalian fauna.

Whatever the reasons, the Pleistocene species had probably disappeared by the end of the glaciation, and the fauna of the land bridge at the time it began to break up was that of Tasmania today, with the addition of two species, *Aepyprymnus rufescens* and *Pseudomys novae-hollandiae*. Between the time the islands finally took shape at about 8,000 years ago, and the arrival of European explorers at the end of the 18th century, several Tasmanian species, mainly those that have been recorded only from Ranga Cave, had disappeared completely from the islands. These were probably affected by the reduc-

tion or disappearance of their habitat on the islands, due either to a reduction in size of the islands, to climatic change or to a combination of both factors. Wetter habitats were certainly more extensive on King Island in the past, as elements of the Tasmanian rainforest grew there about 37,500 years ago (Jennings 1959, 1961).

Among the mammal species that disappeared during this time are the rodents *Mastacomys fuscus* and *Pseudomys higginsii*. *Mastacomys fuscus* is found today in tussock sedgeland and *P. higginsii* in rainforest areas in Tasmania (Green 1968) and both these species probably died out on the islands because of the reduction of their habitats. The brown bandicoot, *Perameles gunnii*, also died out on the islands at an early date as it has been recorded only at Ranga Cave, while the short-nosed bandicoot, *Isodon obesulus*, is still present in open grassland on West Sister Island in the Furneaux Group. The latter has also been found among the sand dune fossils from Flinders and Cape Barren Islands, and although it is no longer extant on these islands, it was recorded alive on Flinders Island in 1832. It is difficult to understand why *Perameles* should disappear and *Isodon* survive since Heinsohn (1966) found that the latter prefers dense vegetation in Tasmania, while *Perameles* is commonly found in open grassland. A similar situation occurs in the distribution of the two rat-kangaroos in Tasmania and the islands. The eastern bettong, *Bettongia gaimardi*, which in Tasmania inhabits the drier and more open sclerophyll forests, has never been recorded from the islands, while the southern potoroo, *Potorous apicalis*, which prefers densely vegetated areas, still occurs on Flinders and King Islands. Again, the eastern native cat, or quoll, *Dasyurus viverrinus*, recorded on the islands only at Ranga Cave, is found in dry sclerophyll-heathland habitats in Tasmania, while the tiger cat, *Dasyurus maculatus*, which may be still extant on the larger islands, prefers wetter habitats. However, it is likely that many of the islands were covered with thick shrubland until cleared within the last 170 years (Guiler 1967), and King Island, at least, was partly vegetated with wet sclerophyll forest. The three species *I. obesulus*, *P. apicalis* and *D. maculatus* have certainly suffered more than the other larger mammals on the islands from modern land development and clearing.

Two species in the Ranga Cave deposit, *Aepyprymnus rufescens* and *Pseudomys novaehollandiae*, have not been recorded alive in Tasmania or on the islands. On the mainland, both species are well represented on fossil deposits in Victoria

and New South Wales (Wakefield 1964, 1967a; Mahoney & Marlow (1968), but their present distribution is very restricted. *Aepyprymnus rufescens* is found only in coastal regions of northern New South Wales and southern Queensland (Marlow 1957) and *P. novaehollandiae* survives in small colonies on the central coast of New South Wales and on the Mornington Peninsula in Victoria (Seebeck & Best 1970). Since the restriction of their range is not confined to Tasmania and the islands of Bass Strait it is probably unrelated to factors operating only in this latter area.

There are only two island populations of species that are not also present in Tasmania, and which do not have a fossil history in the area. These are the populations of *Rattus fuscipes* and *Antechinus minimus maritimus* on Great Glennie Island. This island is only about 6 km from Wilsons Promontory, so the two species may be recent immigrants from the mainland. It is not surprising that there are no more immigrant populations on the islands of Bass Strait, since the predominant ocean currents in the strait are strongly westerly (with a tendency to southwesterly) and easterly (Wyrki 1960). Macintosh (1949), in a study of possible Aboriginal migration routes across Bass Strait, concluded that there was little likelihood of a raft being carried from Victoria to the larger islands of Bass Strait or to Tasmania, although it would be possible for one from western Tasmania to reach Victoria or the eastern islands of the Strait. His results are equally applicable to animal rafting.

Table 5 gives the distribution of the herbivorous marsupials in Tasmania, King Island and on the islands of the Furneaux and Kent Groups at the time of European settlement (taken at 1800) and at present (taken as 1967, the time of this study). Smaller marsupials and rodents have been excluded because of the lack of information about their distributions; no mammals have been recorded from the many islands of less than 0.9 sq km in area. Erith and Dover Islands in the Kent Group are listed as one island, since they are linked by a rocky swashway and have probably been effectively one island in the past.

Faunal records from the Hunter Group are also omitted from the Table, as they were certainly visited by Aborigines from Tasmania in pre-contact times (Meston 1936) and their fauna may have been affected by Aboriginal hunting and burning. Robbins Island, the largest of the group, is about the same size as Clarke Island, and Hunter and Three Hummock Islands are a little

TABLE 5

DISTRIBUTION OF HERBIVOROUS MARSUPIALS IN TASMANIA AND ON THE ISLANDS OF BASS STRAIT, 1800-1967

| ISLAND | AREA sq km | SPECIES - 1800 | | | | | | | | | | SPECIES - 1967 | | | | | | | | | |
|--------------|---------------|----------------|---|---|---|---|---|---|---|---|----|----------------|-----|---|---|---|---|-----|---|---|----|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| TASMANIA | 67,900 | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| FLINDERS | 1,330 | + | + | + | | + | + | + | + | | | | | + | + | | + | + | | | |
| KING | 1,100 | + | + | + | | + | + | + | | | | | | + | + | + | | + | + | | |
| CAPE BARREN | 445 | + | + | + | | + | | | + | + | | | | + | + | | | | | + | |
| CLARKE | 115 | + | + | + | | + | | | | | | | | | + | | | | | | |
| DEAL | 20 | + | + | + | + | + | + | | | | | | | | + | | | + | | | |
| BADGER | 10 | + | + | | | | | | | | | | (+) | | | | | | | | |
| PRIME SEAL | 8.9 | + | + | | | | | | | | | | | | + | | | (+) | | | |
| VANSITTART | 8.1 | + | + | | | | | | | | | | | | | | | | | | |
| ERITH-DOVER | 7.8 | + | + | | | | | + | | | | | | | | | | + | | | |
| WEST SISTER | 6.1 | | | + | | | | | | + | | | | | + | | | | | + | |
| BABEL | 4.4 | | | + | | | | | | | | | (+) | | | | | | | | |
| EAST SISTER | 4.0 | | | + | | | | | | | | | | | + | | | (+) | | | |
| MT. CHAPPELL | 3.6 | | | | | | | | | | | | | | | | | | | | |
| GREAT DOG | 3.3 | | | + | | | | | | | | | | | | | | | | | |
| PRESERVATION | 3.0 | | + | | | | | | | | | | | | | | | | | | |
| LONG | 3.0 | | | + | | | | | | | | | | | | | | | | | |
| PASSAGE | 2.4 | | | + | | | | + | | + | | | | | | | | | | | |
| FORSYTH | 1.9 | | | | | | | | | | | | | | | | | | | | |
| TINKETTLE | 1.7 | | | | | | | | | | | | | | | | | | | | |
| WOODY | 1.6 | | | | | | + | | | | | | | | | | | | | | |
| KANGAROO | 1.4 | | | + | | | | | | | | | | | | | | | | | |
| GOOSE | 0.9 | | | | | | | | | | | | | | | | | | | | |
| GREEN | 0.9 | | | | | | | | | | | | | | | | | | | | |
| LITTLE DOG | 0.8 | | | | | | | | | | | | | | | | | | | | |
| LITTLE GREEN | 0.8 | | | | | | | | | | | | | | | | | | | | |

KEY

| | |
|----------------------------------|------------------------------------|
| 1. <i>Macropus giganteus</i> | 6. <i>Vombatus ursinus</i> |
| 2. <i>Macropus rufogriseus</i> | 7. <i>Trichosurus vulpecula</i> |
| 3. <i>Thylogale billardierii</i> | 8. <i>Pseudocheirus peregrinus</i> |
| 4. <i>Potorous apicalis</i> | 9. <i>Isiodes obesus</i> |
| 5. <i>Bettongia gaimardi</i> | 10. <i>Perameles gunnii</i> |

? Possibly extinct before 1800; recorded only as subfossil

() Introduced.

smaller. Walker Island is actually the northern part of Robbins Island and the channel between the two dries. It seems likely that *Macropus rufogriseus*, *Thylogale billardierii*, *Potorous apicalis* and *Trichosurus vulpecula* were originally on Rob-

bins and Hunter, *M. rufogriseus*, *T. billardierii* and *P. apicalis* on Walker, and *T. billardierii*, *T. vulpecula* and *I. obesus* on Three Hummock.

Many of the herbivorous species survived until 1800 only on the larger islands, and the smaller

ones before this time carried only one or two species, the most persistent being *Thylogale billardierii*. The minimum area for the support of one herbivorous marsupial species in Bass Strait before 1800 seems to have been 1.4 sq km (about 0.5 sq. miles). Apart from Passage Island, where the three species have been recorded only as fossils and so may have died out well before 1800, the smallest area to support two or more species seems to have been 6.1 sq km (about 2.3 sq miles). Main (1961) found similar area/species ratios for macropod species on islands off Western Australia, where the smallest island supporting one species is 0.4 sq miles (about 1.0 sq km). Eleven islands between 0.4 and 6.0 sq miles (15.5 sq km) support one species, and four islands between 18 (46.5 sq km) and 240 (622 sq km) sq miles each support three species. There are no islands in the size range 6-18 sq miles (15.5-46.5 sq km) off Western Australia. In Bass Strait there are no records of marsupials from Green and Goose Islands in the Furneaux Group, both of which are 0.9 sq km (0.4 sq miles), the same size as the smallest of the Western Australian islands. This may be due to the presence of the Cape Barren Goose, *Cereopsis novaehollandiae*, which is a herbivore and presumably a competitor to the marsupials. Badger, Mt. Chappell and Goose Islands in the Furneaux Group are its main breeding islands, but Green Island also maintains a high population of geese (Guiler 1967). No marsupial species have been recorded from Mt Chappell Island either, though it is larger than several which are known to have supported *T. billardierii*. Here it is more likely that competition for the limited resources of the smaller islands determined how many species survived on each.

After 1800 the mammals on the smaller islands disappeared quickly because of hunting pressure. Early reports indicate that on some islands, such as Preservation, the larger marsupial species were wiped out in only a few years. The faunas of the larger islands have survived rather better. The wombat, *Vombatus ursinus*, and also an emu, *Dromaius ater*, disappeared from King Island in the 19th century. The wombat has also gone from Cape Barren and Clarke Islands, and Clarke Island has also lost *M. rufogriseus*. Flinders Island seems to have lost only *Isodon obesulus*. The Tasmanian devil, *Sarcophilus harrisii*, may not have died out in Flinders Island until after 1800 as it is the only species recovered from the sand dunes there that is not otherwise recorded from the island since that time. It may have been overlooked by the

early explorers, as Flinders Island was not inhabited or generally visited until the 1830's. The large scale alterations in habitat due to the extensive clearing and land settlement on King and Flinders Islands and the continual burning of almost all the islands may not have had their full effect yet. These factors, however, are probably responsible for the decline of *Potorous apicalis* and *Dasyurus maculatus* on the larger islands and these species probably have little chance of survival.

DISTRIBUTION PATTERNS IN BASS STRAIT

The island faunas of Bass Strait display two main distribution patterns that must have originated on the Pleistocene land bridge connecting Tasmania to the mainland. The first of these is the difference in faunal composition between the eastern and western islands. The second, and more important, is the disjunction between the mainland fauna to the north of Bass Strait and the Tasmanian fauna on the islands to the south. In both cases the pattern is found in other vertebrates as well as in the mammalian fauna.

THE DIFFERENCE BETWEEN THE EASTERN AND WESTERN FAUNAS

Littlejohn and Martin (1965) found that of the ten species of frogs in Tasmania, four are widespread in Australia and two endemic species are restricted to Tasmania itself and not found on any island. Of the remainder, two species are common to Tasmania, King Island and Victoria. They concluded that the difference in distribution between King Island and Flinders Island indicated that the western side of the Pleistocene land bridge was wetter than the eastern side. Rawlinson (1967) found a similar distinction between the reptile faunas of King and Flinders Islands. The latter has three species shared with Tasmania which are absent from King Island. These three species probably had a very restricted distribution during the Pleistocene, while those species common to Tasmania and both King and Flinders Islands have a wide range on the mainland. Rawlinson suggested that the eastern side of the land bridge was more suitable as a corridor for reptiles, probably due to its greater ecological diversity, while only the more tolerant reptile species were able to use the western side.

There are also some differences between the avifaunas of eastern and western Bass Strait. On King Island the mainland influence is more pronounced, as several bird species reach the southern limit of their range there, while only one non-

Tasmanian species has been reeorded from the Furneaux Islands (Green & McGarvie 1971). The King Island emu, *Dromaius ater*, which like the wombat, became extinct there during the last century was apparently absent from the eastern islands. The emu was smaller and stockier, with shorter legs than any of the other emu species, and Green and McGarvie have suggested that it may have adapted to the denser vegetation on King Island in a way parallel to the cassowary of the tropical rainforests.

While most of the mammal species recorded from Bass Strait are widespread there and in Tasmania, a few appear to follow the pattern displayed by the amphibians and reptiles. The grey kangaroo, *Macropus giganteus*, is now restricted in northeastern Tasmania, and historical records such as those of G. A. Robinson for the 1830's (Plomley 1966) suggest that at the time of European settlement it inhabited the open savannah country of eastern Tasmania, and was absent from western Tasmania. In Bass Strait fossil remains of this species have been found only in the eastern chain of islands, at Ranga Cave on Flinders Island and in the sand dunes of Deal Island, in the Kent Group (Le Souef 1891). However, *M. titan* has been recorded as a fossil from Seotehtown Cave, in northwestern Tasmania (Gill & Banks 1956), and this species may be merely a larger Pleistocene variety of the modern grey kangaroo (L. G. Marshall, pers. comm.). Several other species which prefer open country, the eastern native cat, *Dasyurus viverrinus*, and the barred bandicoot, *Perameles gunnii*, have also been recorded only from Flinders Island. This may be just due to collecting bias as those species are known only from the fossil deposit at Ranga Cave, and no equivalent deposit has yet been found from King Island. Similarly the lack of records of the extinct Pleistocene species from the Furneaux Group and eastern Tasmania is probably due to the fact that no suitable deposits have yet been investigated there.

The southern potoroo, *Potorous apicalis*, shows a cline in size and colour from east to west across northern Tasmania, potoroos from the northwest being small and rufous-brown, while those from the east are large and grey-brown (Hope 1969). The modern population of potoroos on King Island is indistinguishable from those in northwestern Tasmania. In eastern Bass Strait, the modern populations on Flinders and Clarke Islands are small and grey-brown. The remains of small potoroos have also been recovered from the sand dunes on Deal and Cape Barren Islands. Fossils of *P. apicalis* from Ranga Cave are much

larger than the modern potoroos from Flinders Island and approach the modern eastern Tasmanian ones in size. It seems that the present cline across Tasmania was already in existence on the land bridge before the islands were isolated postglacially. The potoroos on the eastern islands have diminished in size since then, so that their similarity in size to the modern potoroos on King Island and in western Tasmania may be due to convergence.

These differences between east and west correlate very well with the present precipitation gradient across Tasmania. Those that occur on the islands must date back to the time that the land bridge was in existence, suggesting that the precipitation gradient must have been as strong across the Bassian peninsula in the Pleistocene as it is across Tasmania today.

THE DISJUNCTION BETWEEN THE NORTHERN AND SOUTHERN FAUNAS

The vertebrate fauna of the Bass Strait islands is basically that of Tasmania, so that the disjunction between the southern Tasmanian and the northern mainland faunas occurs at the northern extreme of Bass Strait, close to the Victorian coastline. In particular, most of the species and subspecies endemic to Tasmania are present on the islands as well as in Tasmania. The main exception to this is in the amphibia, where the two endemic frog species are restricted to Tasmania itself. However, two of the four endemic reptile species occur on Flinders Island as well as in Tasmania (Rawlinson 1967) and one occurs on King Island (Green & McGarvie 1971). Of the 14 endemic Tasmanian bird species, 11 have been recorded from King Island and 8 from Flinders Island (Ridpath & Moreau 1966, Green 1969 and Green & McGarvie 1971). Undoubtedly some of the endemic Tasmanian bird species are in fact relict species which once had a wider distribution, as Ridpath and Moreau have suggested.

Since mammals have a reasonable fossil record in Australia, it is possible to eliminate from the list of endemic species those which are now extinct on the mainland and are relict species in Tasmania. In fact, all three of the mammal species that are now endemic to Tasmania, *Thylacinus cynocephalus*, *Sarcophilus harrisii*, and *Pseudomys higginsii*, have been recorded as fossils on the mainland. The first two had extensive distributions throughout Australia during the Pleistocene, and the thylacine also reached New Guinea. There is nothing to suggest that either species originated in Tasmania. The remaining species, *P. higginsii*, has recently been recorded in

fossil deposits at Buchan, Victoria, and Wombeyan Caves, N.S.W. (Wakefield 1972). Wakefield has described these fossil populations as a subspecies distinct from the modern Tasmanian one.

The Tasmanian populations of several mammals are also regarded as subspecifically distinct. These are *Tachyglossus aculeatus setosus*, *Antechinus swainsonii swainsonii*, *A. minimus minimus*, *Pseudocheirus peregrinus convolutor*, *Trichosurus vulpecula fuliginosus*, *Bettongia gaimardi cuniculus*, *Macropus rufogriseus rufogriseus* (on King Island only) and *M. r. fruticosa* (Tasmania and Flinders Island) and *Rattus lutreolus velutinus*. Many of these have often been considered to be full species. All are present on the islands of Bass Strait except *B. g. cuniculus* and *A. s. swainsonii*, which have never been recorded there alive or fossil.

The presence of the endemic Tasmanian subspecies on the islands of Bass Strait suggests that their differentiation must predate the last 8-10,000 years that the islands have been isolated from Tasmania. It is likely that speciation occurred in Tasmania when that island was isolated from the mainland during an interstadial or interglacial. The initial presence of the Tasmanian species and subspecies rather than the mainland ones on the land bridge that subsequently developed during the low sea level glacial period would be ensured by the topography of Bass Strait, the deepest water of which is at the N. The Tasmanian species would thus have an advantage over the mainland species and would be more likely to be isolated on the islands formed at the end of the glaciation.

The sequence of formation of a land bridge across Bass Strait is the reverse of that described by Jennings (1971) for its postglacial flooding. As sea level fell, the islands of the Furneaux Group would coalesce, and then be joined to northeastern Tasmania. Later King Island would be connected with northwestern Tasmania, and then the Furneaux Group would join Wilsons Promontory, Victoria. Finally the central area of Bass Strait would become dry land and a connection form between King Island and Cape Otway. By the time the final water barrier disappeared between the mainland and the greatly enlarged island of Tasmania, the Tasmanian fauna would have had ample time, perhaps several thousand years, to move N. onto the developing land bridge, driven perhaps by the deterioration of climate in central Tasmania, and to become established there before coming into contact with the mainland fauna. The first line of contact between the southern fauna and the northern, main-

land one would have been somewhere N. of the Hogan Group within 30 km of the present Victorian coastline. In short, the Tasmanian species would be moving N. onto uninhabited, newly exposed land as the sea level fell, but mainland species attempting to move S. would be met with the Tasmanian fauna already established on the land bridge.

When the southern and the northern faunas met, at a line somewhere S. of the Victorian coastline, several things may have happened. If a population isolated in Tasmania had differentiated sufficiently so that it was no longer capable of interbreeding with its mainland relative, then when the two met at the N. of the land bridge, the boundary between the species could have stabilized at the point of contact, with neither species able to displace the other. In such a case the Tasmanian species would be the one found on the islands when the land bridge broke up at the end of the glaciation. However most of the mammals that fall into this category (that is, where the island populations are the Tasmanian endemic form rather than the closely related mainland one) are generally regarded only as subspecies. If they are merely subspecies, then some interbreeding should have occurred between the mainland and Tasmanian forms on the land bridge, so that the present island populations would be intermediate between the two. This may be the case with some birds. Populations of *Acanthiza* and *Sericornis* on the Kent Group have generally been considered to be the Tasmanian endemic species, *A. ewingi* and *S. humilis* (Ridpath & Moreau 1966). Jones (1972) quotes I. Abbott, who considers that they are in fact the more widespread mainland species, *A. pusilla*, which also occurs in Tasmania and on King Island, and *S. frontalis*. He considers that *S. humilis* is possibly 'not a good species, in which case variation of *Sericornis* over south-east Australia and Bass Strait is clinal . . . the Deal Island population is intermediate in many respects between the Victorian and Flinders Island populations'.

Where the island populations are not intermediate in characteristics, but are similar to the Tasmanian forms, then they may in fact be good species on the islands and in Tasmania. A possible example of this is the population on Hogan Island, to the northwest of the Kent Group, of *Rattus lutreolus* which is the Tasmanian subspecies *R. l. velutinus*. Specimens collected there differ significantly from the Tasmanian population in only one cranial measurement, interorbital width, the Hogan Island rats being somewhat

smaller (Wakefield 1969). Since this population must have maintained itself distinct from the mainland population at about the line of contact, just N. of the Hogan Group, during the existence of the land bridge, it is likely that the Tasmanian and island rats are a good species.

Some further differentiation may have occurred in the island populations since the land bridge was finally flooded, as in the populations of *Potorous apicalis* in the Furneaux Group; this may account for the additional island subspecies that have been named, such as the two forms of *Macropus rufogriseus*, and the Flinders Island population of the ringtail possum. Further studies on the variation of island populations are needed; particularly, attempts to distinguish persisting variation that is due to interbreeding between Tasmanian and mainland populations on the land bridge during the Pleistocene, from variation that is due to the isolation of small populations on the islands over the last 10,000 years.

If a species that evolved in Tasmania did not meet any resistance from the mainland fauna, it may have been able to invade the mainland and become established there. There are three obvious possibilities among the mammals, *Antechinus minimus*, *Thylogale billardieri* and *Perameles gunnii*. *Antechinus minimus* has the barest foothold on the Victorian coast (Wakefield & Warneke 1963) and has been just as restricted in its past distribution, at least during postglacial times, as it is not recorded from any Victorian cave deposits (e.g. Wakefield 1964, 1967a, 1967b). Similarly, *Thylogale billardieri*, which has become extinct on the mainland during historical times, is recorded there during the late Pleistocene and Recent only from cave deposits close to the Victorian coast, such as McEacherns Cave and Fern Cave on the lower Glenelg River, and Tower Hill Beach and Bushfield (Wakefield 1964, 1967a, 1967b). *Perameles gunnii* has a wider distribution than these two species, but has been recorded only from western Victoria. Littlejohn (1967) lists several amphibian species that he suggests evolved in Tasmania and migrated north onto the mainland.

Some species widespread on the mainland may have been absent from Tasmania until the Late Pleistocene land bridge allowed them to move south. Most in this category would be those species in which the island and Tasmanian populations do not differ from the mainland ones. Within Tasmania there are several examples of closely related species pairs, one of which presumably evolved there during an earlier period of isolation, while the other moved south over a

later land bridge. In these cases, the endemic species or the more distinctive (and presumably the older) of two endemics is usually the only one found on the islands or is the more common on the islands. For example, Ewings Thornbill, *Acanthiza ewingii* is endemic to Tasmania, but is also found on King and Flinders Islands (Ridpath & Moreau 1966). The related Brown Thornbill, *A. pusilla diemensis*, an endemic subspecies in Tasmania, has been recorded in Bass Strait only from King Island, where it is much rarer than *A. ewingii* (Green & McGarvie 1971). Similarly, of the two endemic currawongs found in Tasmania, *Strepera fuliginosa* and *Strepera arguta*, only the more highly differentiated, *Strepera fuliginosa*, has been recorded from the islands, where it is found on both King and Flinders (Serventy 1967). No exact parallel occurs in the mammals, but the species pair of *Antechinus minimus* and *A. swainsonii* is comparable. *Antechinus minimus*, though not endemic to Tasmania, may have originated there, as on the mainland it is restricted to a few isolated localities on the southern coast of Victoria (Wakefield & Warneke 1963). In contrast, *A. swainsonii* is widely distributed in coastal New South Wales and Victoria. Yet only *A. minimus* is found on the Bass Strait islands. In the case of the birds, the species more widespread on the islands is living there in a habitat inconsistent with that which it favours in Tasmania. Both *Acanthiza ewingii* and *Strepera fuliginosa* are found only in wet sclerophyll habitats in Tasmania, while the species rare or missing from the islands, *A. pusilla* and *S. arguta* occur in dry sclerophyll areas. Yet on the islands *A. ewingii* and *S. fuliginosa* are found in these drier habitats. This parallels the distribution of some mammals as mentioned earlier, where *Potorous apicalis*, *Isodon obesulus* and *Dasyurus maculatus*, all of which prefer wetter habitats, are living on the islands while the similar species, *Bettongia gaimardi*, *Perameles gunnii* and *Dasyurus viverrinus*, found in drier habitats in Tasmania, are absent. In contrast, *Antechinus swainsonii*, which is not found on the islands, inhabits rainforest in Tasmania, while *A. minimus*, the island representative of the pair, prefers open unforested areas and is found in Tasmania's buttongrass plains and coastal sedgelands.

Some species have moved south into Bass Strait but have not reached Tasmania. Green and McGarvie (1971) noted that several birds reach the southern limit of their range at King Island, and one does so at Flinders Island. Among the mammals only extinct species, such as *Diprotos-*

don optatum on King Island and *Aepyprymnus rufescens* on Flinders Island have been recorded from the mainland and the islands, but not from Tasmania. But in these cases, their apparent absence from Tasmania could be due to the poor state of knowledge of the Tasmanian fossil record.

There are several mainland species of mammals which, considering their distribution and habitat, could be expected to have moved into Tasmania at the same time of the land bridge but apparently did not do so. Parallel cases among reptiles and amphibians have been explained as postglacial intrusives, that is, species which had more northerly distributions on the mainland during the Pleistocene, and which did not move into southern Victoria until the connections across Bass Strait had been severed (Rawlinson 1967, Littlejohn & Martin 1966). All the mammal species cannot be accounted for in this way, as some, such as the koala, *Phascolarctos cinereus* and the swamp wallaby, *Wallabia bicolor*, are found in late Pleistocene and Recent deposits throughout southern Victoria, and suitable habitats for these species now exist in Tasmania and on the islands. It is possible that some of these species reached Tasmania, or at least moved south onto the land bridge during the Pleistocene and later died out. Like *Aepyprymnus rufescens*, they may yet be found as fossils within Tasmania or on the islands.

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BIRDS OF BASS STRAIT

Evolution and Ecology of the Avifaunas of some Bass Strait Islands, and Comparisons with those of Tasmania and Victoria

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ABSTRACT: Up to about 18,000 years ago when Tasmania was a peninsula of Australia, the exposed Bass Strait plain was probably important in the evolution and ecology of Bird species at present endemic to the Tasmanian region. The large Bass Strait islands and Tasmania have 12%-17% of their species not shared with the mainland, a high figure compared with that of the other Australian offshore islands. It is difficult to attribute this unequivocally to distance from the nearest mainland or age of the islands. The Bass Strait islands and Tasmania have only 15%-50% of the passerine species breeding in Southern Victoria. A plot of number of breeding forest passerines on these islands against island area A does not adequately approximate the equation $S = kA^z$, especially for islands smaller than about 40 km². This, and other evidence, points to passerine species having very low immigration and invasion rates onto islands. The pattern of distribution of land bird species on the islands is largely relict. A provisional scheme of their evolutionary history in the Tasmanian region of Bass Strait is proposed. Fifty-one species are postglacial intrusives into Southern Victoria.

It is unnecessary to fall back on competitive exclusion to explain the impoverishment of the island avifaunas. There is no convincing evidence that on the Bass Strait islands and Tasmania passerine species change in bill and leg dimensions to exploit unfilled niches. Some populations of the same species differ from island to island in their feeding zonation, suggesting intrinsic but as yet unresolved differences in food supply. Absence of mainland bark-probing species from the Tasmanian region of the Strait does not satisfactorily explain why only some island populations of some species feed from bark. A similar lack of evidence for changes in morphological variation (bill length, tarsal length) of island populations of passerines suggests that the theoretical importance given to competitive processes warrants evaluation.

INTRODUCTION

Frequent questions about bird populations on islands are whether, and if so why

1. Islands have fewer species than comparable areas of adjacent mainlands.
2. Islands have fewer congeneric species than an equivalent area of mainland.
3. The distance from an island to the nearest mainland influences the rate of colonization, and the size of the island affects the rate of extinction of species.
4. Bird species on islands have longer bills and legs, and/or a wider range of variation in bill size and tarsal length, than mainland species.
5. Bird species on islands have more generalized

habits, such as the wide range of sizes of food items taken and of habitats occupied.

Such questions have been given serious attention by Grant (1965, 1966a), MacArthur and Wilson (1967) and Laek (1971).

Bird populations of Australian offshore islands (of which there are about 1300 (Anon. 1912)) have up to now escaped such detailed analyses. Early this century when taxonomy for its own sake was in vogue (Campbell 1900, Mathews 1912), visitors to islands went there solely to seek new species or subspecies. A happy by-product was that many lists of the birds found there were published (bibliography in Abbott 1972). These have been invaluable aids for com-

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parisons by later visitors. The larger islands in Bass Strait, as well as Tasmania, were often visited by members of the Royal Australasian Ornithologists' Union and the Field Naturalists' Club of Victoria, probably because these organizations were based in Melbourne. Modern lists, also, of birds of the islands in Bass Strait have been compiled by workers more specifically interested in the distribution and abundance of species. These form a basis for a study of the ecology and evolution of passerine bird species in particular.

On the basis of the axiom that no two species can co-exist for long before one acquires numerical superiority over the other, workers such as Grant (1965, 1966a), MacArthur and Wilson (1967) and Lack (1971) hold that competitive processes are the keynote to an understanding of the ecology and evolution of bird species on islands. From this same viewpoint, Ridpath and Moreau (1966: 372) explain why Tasmania has fewer bird species than equivalent Victorian habitats. None of these workers, however, adequately consider another aspect: that Bass Strait was and is a substantial physical barrier separating many Victorian species from Tasmania and the Bass Strait islands.

Such a 'barrier viewpoint' can be elaborated to serve as a basic model of probable history for the birds of the islands in Bass Strait and of Tasmania, especially to explain the high degree of species endemism, and on the islands the impoverished avifaunas. In this paper, such a model is tested with data from the literature and discussed in terms of the views of Ridpath and Moreau (1966) and of Lack (1971).

ENDEMISM

It has long been noted (e.g. Flinders 1801) that islands hold more endemic species than continental areas many times their extent. To pursue this observation the bird species restricted to King, Flinders, Cape Barren and Deal Islands and Tasmania are here tabulated (Table 1), and the question of Tasmanian influence on the high number of endemic bird species held by the Bass Strait islands is considered. Also, the numbers of such endemic species found in other animal groups, and of plant families that dominate the vegetation of the larger islands are listed (Table 2) to see which parallels there are, if any. To determine which factors might decide the number of endemic bird species on an island, lists of parameters for other Australian islands are given (Table 3). Data from overseas areas are quoted where relevant.

Tasmania and the islands in Bass Strait, being continental islands, have been alternately joined

to, and separated from Victoria throughout the Pleistocene (Jennings 1971). Some bird species have reached Tasmania during an early glacial and evolved in isolation during the subsequent interglacial (Serventy 1967a). During the later glacial, a similar species has reached Tasmania. Two such species are known as members of a double invasion. Because of the position of the islands in Bass Strait, it is of interest in reconstructing the Pleistocene botany to note whether the older or newer members of the double invasions are present.

1. IMPORTANCE OF TASMANIA

To avoid clumsy circumlocutions, I shall use 'Tasmania (s.l.)' to refer to the situation in the past when Tasmania was a peninsula of Australia, incorporating all of the present Bass Strait islands into a land bridge. The term 'island endemic' will designate species restricted to a single island. Species restricted to two or more islands are called 'island group endemics'. Because only three of the Australian continental islands have endemic bird species that fit the first category (Table 3, last column), little more will be said of this class.

A list of the bird species endemic to the Tasmanian region is given in Table 1. These endemics must have arisen in one of two ways. They either originated in Tasmania (s.l.) (neoendemics) or they originated on the Australian mainland, spread to Tasmania (s.l.), and have since died out on the mainland (relict endemics). For the neoendemics, it is necessary to establish if they originated before or after about 13,000 years ago, when the land link to Tasmania was finally broken (Jennings 1971). Those that evolved after this time may not have gained access to the mainland. On the other hand, those that evolved earlier on Tasmania (s.l.) should have reached the mainland because there is no evidence of any physical barrier that would have prevented their movement northward. In this case, their absence today from the mainland indicates that they are secondarily relict endemics. However it is not conclusively known in which way any of the 13 Tasmanian region endemic species originated.

At the height of the last glaciation, some 20,000 years ago, about 52,000 km² of ground to the north of Tasmania was above sea level (Abbott 1972), and presumably vegetated. Because the 100 m isobath W. and E. of Tasmania lies only 15-20 km from the present shoreline, little extra land was added in these places. Over 80% of Tasmania lies above the 300 m contour, and with a 5°C drop in temperature the tree line would

have been lowered to 500 m above sea level (Gal-
loway 1965) or 300 m (Davies, quoted by Rid-
path and Moreau 1966, p. 359). Thus much of
Tasmania would have been covered with habitat
which today is inimical to most bird species. The
drier *Eucalyptus* forests where most of the en-
demics are very common today (pers. obs.)
would have been greatly reduced in extent. How-
ever, presumably the remainder of Tasmania
(s.l.), being at a lower latitude and altitude, was
covered with *Eucalyptus* dominated habitats. The
Bass Strait area during the last glacial was prob-
ably the focal point of the distribution and abun-
dance of the species which are at present endemic
to the Tasmanian region.

Ridpath and Moreau (1966: 385) reasoned
that because many of the Tasmanian region en-
demic species are scarce or absent in *Notho-
fagus/Phyllocladus* habitat, they entered Tas-
mania later than about 18,000 years ago. Further,
because some of these species occur on King Is-
land (which became an island about 11,000 years
ago), such species must have originated between
18,000 and 11,000 years ago. If this is so, argue
Ridpath and Moreau, these species existed while
the eastern side of Bass Strait was still a land
bridge, with no known barrier to movement into
Victoria. Because the species are unknown in Vic-
toria, Ridpath and Moreau assume that the en-
demics did survive the glaciation in Tasmania after
all, thus contradicting their original premise. They
do not consider that the endemics could be relict.
However, Serventy (1967b) argues against the
likelihood of species evolved on islands success-
fully colonizing a mainland. He follows Darwin
in postulating that species evolved on large land
masses have a competitive advantage over others
not so evolved. But this postulate ignores the fact
that as a result of past climatic changes, the Aus-
tralian mainland avifauna has many times been
broken up into a series of isolates (Keast 1961).

My interpretation is that the presence of Tas-
mania may not have made much difference to
the production of bird species that are at present
endemic to Tasmania and the Bass Strait islands.
However, Tasmania may have provided some of
the basic stocks which differentiated during inter-
glacial stages on the exposed Bass Strait plain.

2. ENDEMISM IN OTHER GROUPS

Investigations were made to establish any con-
sistent patterns in endemism among plant and ani-
mal groups in the Tasmanian region. Data for
four prominent families of plant species, and for
mosquitoes, amphibians, reptiles, birds and mam-
mals are presented in Table 2. The plant families
Mimosaceae, Myrtaceae, Proteaceae and Epacri-

daceae are prominent in much of the vegetation of
Tasmania, the Bass Strait islands, and Victoria.
Mimosaceae and Myrtaceae contain the genera
Acacia and *Eucalyptus*, of obvious importance in
the habitat of forest birds.

Only three of the taxa listed in Table 2 have
Tasmanian endemics on the Bass Strait islands.
These are Proteaceae, Reptilia and Aves. The ab-
sence of any uniform pattern surely indicates the
taxa have had very different places of origin and
subsequent dispersal and distribution. A little is
known of the latter for some taxa, e.g., in the past
some of the Tasmanian endemic mammals have
occurred in the Furneaux and Kent groups (Hope
1969).

Birds are the only group to have endemic spe-
cies shared with Tasmania present on all the ma-
jor islands in Bass Strait (Table 2). However, it
is surprising that King Island should have a
higher percentage of endemic bird species than
the Furneaux Group, wherein the largest island
(Flinders Island) is about 200 km² larger than
King Island. Also, King Island does not have the
topographic diversity that Flinders Island has
(highest points are 210 and 750 m respectively),
nor does it have the variety of habitats or number
of plant species that Flinders Island has (pers.
obs.). This indicates that these factors, usually
given *prima facie* importance in island studies,
are irrelevant in explaining the discrepancy.

3. COMPARISON WITH OTHER AUSTRALIAN CONTINENTAL ISLANDS

The number of endemic bird species that an
island has today is related to the age of the island.
If young, there may have been insufficient time
for endemic species to evolve (or for species
shared between the island and mainland to be-
come extinct on the mainland). If old, endemic
species may have become extinct or established on
the mainland. This time factor is probably modi-
fied according to the ecology of the island. We
can therefore attempt to assess the potency of a
number of easily measured factors in explaining
differences in the number of endemic bird species
on islands around Australia.

Factors considered are (1) minimum distance
at present separating an island from the mainland,
(2) area and greatest height as a measure of the
ecology of the island, and (3) time of isolation
(calculated from a graph in Hails 1965). These
data, along with the number of bird species not
shared with the mainland and the number of bird
species restricted to each island, are listed for all
the major islands in Table 3. Apart from Tas-
mania and the islands in Bass Strait, only three
islands (Kangaroo, Dirk Hartog and Barrow)

hold species (one each) which are absent from any mainland. This is less than 5% of the avifauna of these islands, and is much lower than the figure (12%-17%) for Tasmania and the large Bass Strait islands (Table 2). Although Tasmania has numerically more non-mainland species than any other Australian island, King Island has proportionately more, both for its area and avifauna (Tables 2, 3).

Only three islands have species that are restricted to one island (one island endemics). These are King and Kangaroo Islands and Tasmania (Table 3, last column). With the data assembled (Table 3), it is difficult to separate distance of island from mainland and age of island, because the islands with most endemics are generally farthest from the mainland, and are also the oldest. Furthermore, some islands (Barrow, Dirk Hartog, Kangaroo) which have been separated from the mainland only a short time also have endemic species.

The oldest island, but not the one that is most distant from the mainland, is King Island (Littlejohn and Martin 1965) (Table 3). Of the species in its avifauna 17% are not shared with the mainland. The next oldest large islands—Flinders, Cape Barren and Tasmania—have about 12% of the species in their avifauna endemic. The modifying effect of island size and ecology is apparent in the case of Deal Island and the islands of Houtman Abrolhos. Because Deal Island (in the Kent Group) lies within the 55m isobath, the Kent and Furneaux Groups were part of one large island until the sea had risen to about the 35m isobath, that is for approximately 1000 years (Abbott 1972). During this time these groups probably shared avifaunas, so that the absence from Deal Island today of eight of the Tasmanian region endemics which are on Flinders Island is probably due to extinction. This is not surprising, since Deal Island is about 1% of the area of Flinders Island. On the other hand, King Island has separated from Tasmania with most of the Tasmanian region endemics.

Although Houtman Abrolhos was the next island group to be separated from the mainland, it consists of numerous small, low islets which would not be expected to support endemic species.

Lack (1970) has argued against the view that endemism in island birds is correlated with isolation, which he takes to be represented by distance from the mainland. Data in Table 3 support Lack, since some large, close islands (Dirk Hartog, Kangaroo) have endemic species while islands of similar size, but more distant (Melville, Groote) do not. These large islands are

0.5-5 times the area of King Island (Table 3). Isolation, represented by age of the island, may be a more realistic parameter, though the correlation again is not perfect. For example, Bernier Island has one endemic, but the older Melville island has none. Very old non-continental islands (isolated before 18,000 years ago), such as Lord Howe, Norfolk, and New Zealand have about 50-60% of their avifauna endemic (Abbott 1972). However these islands are also far from the nearest mainland. Madagascar, which is only 405 km from Africa, has 70% of its avifauna endemic. The minimum depth of the intervening strait is over 1000m, implying long isolation (Moreau 1966).

4. MULTIPLE INVASIONS AND COLONIZATIONS

Multiple invasions are cases where two or more closely related species occur on the Bass Strait islands and/or Tasmania with only one existing on the mainland (Mayr 1942). The first invading species diverges most from the mainland stock, and is the species not found today in Victoria. The newer invader is sufficiently different from the first not to interbreed; it is the species found today on mainland Victoria. Where there are two closely related species on the mainland, the situation may be called a double colonization. Serventy (1967a) discussed two examples in detail—*Acanthiza ewingi* and *A. pusilla* (double invasion), and *Strepera graculina* and *fuliginosa*, and *S. versicolor* and *arguta* (double colonization). Serventy conjectured that the older member of the double invasion or colonization alone occurs on the Bass Strait islands. New information, not available to Serventy, is summarized in Appendix Table 1A.

The older invaders which are present on the islands in Bass Strait are *Pardalotus quadragintus*, *Acanthiza ewingi*, *Melithreptus affinis*, *Acanthornis magnus*, *Sericornis humilis*, *Platycercus caledonicus* and *Strepera fuliginosa*. The newer invaders occurring on these islands are *Pardalotus punctatus*, *Acanthiza pusilla*, *Melithreptus lunatus*, *Sericornis frontalis* and *Platycercus elegans*. Thus, *Strepera fuliginosa* is the only case where the older invader is found alone on the Bass Strait islands.

It has been suggested that at the time of isolation of the Bass Strait islands, they supported mostly rainforest/wet sclerophyll habitats (Green 1969). The evidence from double invasions of bird species militates against this view because the new invaders are not indicative of wetter habitats, and they are as widespread on the Bass Strait islands as are the older invaders.

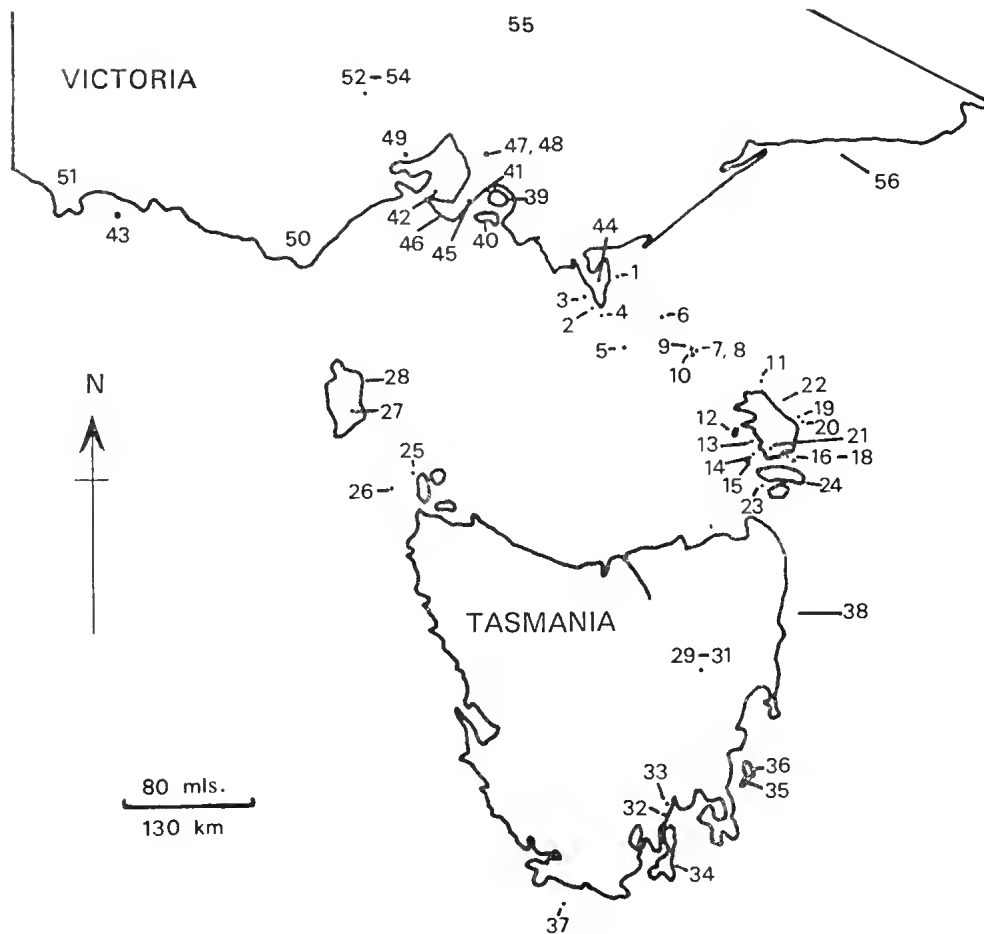


FIG. 1: Location of areas used in Figure 2

ISLANDS: 1. Clifly Island (D. F. Dorward, pers. comm.). 2. Anser Island (D. F. Dorward, pers. comm.). 3. Great Glennie Island (D. F. Dorward, pers. comm.). 4. Rodondo Island (Bechervaise, 1947). 5. Curtis Island (Abbott, unpubl.). 6. Hogan Island (N. Scarlett, *in lit.*). 7. Deal Island (pers. obs.). 8. 10 acre plot, Light-house Gully, Deal Island (pers. obs.). 9. Erith Island (Whinray, 1971). 10. Dover Island (Whinray, 1971). 11. West Sister Island (Whinray, 1972). 12. Prime Seal Island (D. Milledge, unpubl. list). 13. Big Green Island (Norman, 1970). 14. Mt. Chappell Island (D. Milledge, unpubl. list). 15. Badger Island (D. Milledge, unpubl. list). 16. Fisher Island (Guiler, Serventy and Willis, 1958). 17. Tinkettle Island (D. Milledge, unpubl. list). 19. Babel Island (D. Milledge, unpubl. list). 20. Cat Island (Cashion, 1958). 21. 10 acre plot, Smiths Gully, Flinders Island (pers. obs.). 22. Flinders Island (pers. obs., Green, 1969, 1971). 23. Preservation Island (D. Milledge, unpubl. list). 24. Cape Barren Island (D. Milledge, unpubl. list; Whinray, 1970). 25. Albatross Island MacDonal and Green, 1964). 26. Black Pyramid (Green and MacDonal, 1964). 27. 10 acre plot, Rafferty's Gully, Pegarah Forest Reserve, King Island (pers. obs.). 28. King Island (pers. obs.; Green and McGarvie, 1971). 29-31. Four 5 acre plots, Campbell Town, Tasmania (Recher, Thomas and Milledge, 1971). 32. 10 acre plot, east side Mt. Louis (pers. obs.). 33. Mt. Wellington area (D. Milledge, unpubl. list). 34. Bruny Island (McGilp and Parsons, 1924; Mosey, 1947; D. Milledge, unpubl. list). 35. 10 acre plot, NE. of Chinamans Bay, Maria Island (pers. obs.). 36. Maria Island (D. Milledge, unpubl. lists; Temple-Smith, 1968). 37. Maatsuyker Island (D. Milledge, *in press in Emu*). 38. Tasmania (Sharland, 1958). 39. French Island (Quin, 1969). 40. Phillip Island (Pound, 1969). 41. Quail Island (Hyett and Gottsch, 1963). 42. Mud Islands (R. Wheeler, unpubl. list). 43. Lady Julia Percy Island (Pescott, 1965).

MAINLAND AREAS: 44. Wilsons Promontory (Anon, 1970; Barrett, 1920, Bryant, 1930; Kershaw, 1906; Mars-ton, 1969; Pescott, 1967; Quin, 1970; St. John, 1909; Wheeler, unpubl. list; pers. obs.). 45. Somers area, Mornington Peninsula (A. J. Reid and W. A. Davis, unpubl. list). 46. Mornington Peninsula (Wheeler, 1967). 47. Dandenong Ranges area (R. Wheeler, *in press*). 48. Churchill National Park (Bliss, 1969). 49. You Yangs (Hore-Lacy, 1959, 1965). 50. Otway area (Hill, 1902; Wheeler, 1967; Johnson, 1967, pers. obs.). 51. Portland area (Learmonth, 1966). 52-53. 10 and 20 acre plots, Coates Gully, St. George's Lake, and Diamond Gully, Creswick. 54. Creswick district (R. Cowley, unpubl. list). 55. Strathbogie Ranges (Bedggood, 1972). 56. Vic-toria (Wheeler, 1967).

AREA AND NUMBER OF SPECIES

Many attempts have been made to see which factors about islands are most important in determining how many bird species they support. The work of Hamilton et al. (1964) and MacArthur and Wilson (1967) suggests area to be a potent factor, and other factors such as elevation and isolation to be relatively unimportant. Moreau (1966: 359) suggested that the following factors need to be accounted for in explaining the number of species an island has: (1) the history of each island, (2) its degree of isolation; (3) the complexity of habitats it carries, (4) the extent to which its habitats and its bird fauna have suffered from human interference, and (5) the completeness with which the avifauna is known.

Factor (4) has probably affected Hogan Island and some of the small islands in the Furneaux Group, and soon will be of importance for King Island. I do not consider that factor (5) is of major importance for any island except Rodondo Island. MacArthur and Wilson (1967:8) believe that island area may be an adequate measure of (3). Fig. 2 is a graph (on log scale) of the number of breeding (or presumed breeding) passerine species plus one (S) against island area (A). The geographical areas used are shown in Fig. 1. Species considered are those that breed in *Eucalyptus* forest and/or heath, and which belong to the families Dicaeidae, Climacteridae, Neosittidae, Acanthizidae, Maluridae, Rhipiduridae, Monarchidae, Muscicapidae, Pachycephalidae, Falcunculidae and Meliphagidae as defined by Condon (1969). Unqualified use of the term 'species' in the remainder of this section is meant to indicate breeding species in these families only. Because some islands have none of these species breeding, I have avoided log (0) by transforming the number of species N , to $N + 1$. Also included in Fig. 1 are points for areas in mainland Victoria, ranging from 10 acre (0.04 km²) plots to the whole area of Victoria. I have also included points for French, Quail, Phillip, Mud, Lady Julia Percy, Bruny, Maria, and Maatsuyker islands.

MacArthur and Wilson (1967, Ch. 2) hold that a rough approximation for number of species, S , in an island fauna is given by $S = kA^z$, where k and z are empirically determined constants and A is area. With such a relationship, $ds/S = z dA/A$, so that for a given increase in area, species number will always increase in the same ratio. The validity of this equation for areas larger than 1 ml² (9.59 km²) is supported by graphs in MacArthur and Wilson (1967: 8, 10 and 23). However when areas are less than 100 acres (0.40 km²), it is evident that $S = kA^z$ does not

hold (graph in MacArthur and Wilson 1967: 32).

My data for the Bass Strait islands (Fig. 2) show that $S = kA^z$ does not hold over the whole range of A , especially for small and large islands, and for small mainland areas. For the islands the species/area relation might be represented better as

$$\begin{aligned} S &= 0 && \text{for } A < c. 10^3 \text{ acres (c. } 4.0 \text{ km}^2\text{);} \\ S &= kA^z && \text{for } c. 10^3 < A < c. 10^4 \text{ acres;} \\ S &= k'A^{z'} && \text{for } A > c. 10^4 \text{ acres (c. } 40.5 \text{ km}^2\text{)} \end{aligned}$$

That is, in the lower part of the area range, the size of an island below which no breeding passerines are present is a little less than 1000 acres (4 km²). Islands of area between about 1000 and 10,000 acres show a rapid increase in number of species with increasing area, while in the upper part of the area range, the rate of increase drops off markedly (Fig. 2). Possible explanations are discussed later. Fig. 2 very clearly shows that islands of comparable size to a mainland area have far less than the mainland quota of species.

Two explanations are possible, after MacArthur (1965, 1969), to account for this striking difference in the number of species on islands and adjacent mainland. If, on Fig. 2, the vertical distance between the mainland and island lines (drawn in) were constant then the mainland counts would merely be multiples of island counts for equal sized areas. This would result if a mainland area M , with n times the number of species as an island area I of equal size, had each of its component 10 acres (0.04 km²) with n times as many species as each component 10 acres of I . In this case, the explanation of island diversity is local. Once the reason for the decrease in diversity in 10 acres on I is found, nothing else needs to be known to explain why the island avifauna is depauperate. In MacArthur's phrase, the 'within habitat diversity' alone is responsible for the small size of the island avifauna.

A second alternative is that M still has n times the number of species that I has, but the 10 acre plots on M and I have the same number of species. That is, the mainland line has a greater slope than the island line, so that the explanation for the difference cannot be local. The component of 'between habitat diversity' is low on the island, and this is responsible for the impoverished island avifauna.

The first explanation is clearly incorrect. A line (not drawn in) joining points 50-51-52-54 (Creswick area, Victoria) in Fig. 2 is not a constant vertical distance above a line joining points 29, 30 or 31-32-33-38 (Tasmania). In Tasmania, once an area of the size of No. 33 is reached,

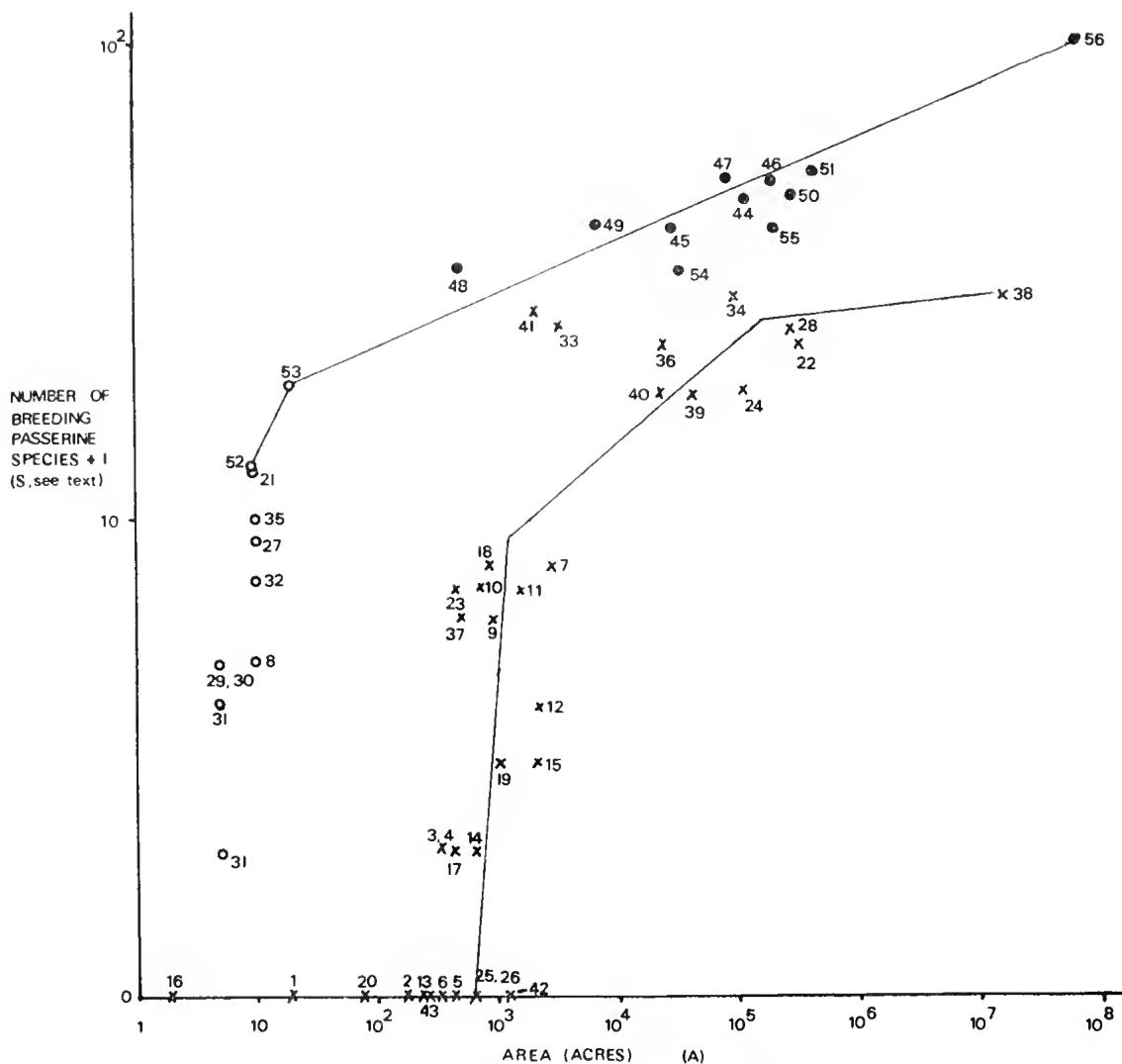


FIG. 2—The number of breeding passerine species (+1) plotted against the area in acres for island and mainland areas. X denotes islands; O censused plot; and ● mainland area.

almost all of the passerine species in Tasmania have been recorded. This probably also applies to extending 10 acre plots on Deal, King and Flinders Islands (Fig. 2). Once an area of about 100-1000 acres (0.4-4.0 km²) has been sampled on an island, not many more new species are likely to be recorded as breeding because most of the available habitats will have been covered. On the mainland, increasing the area adds more habitat types, resulting in many new species being recorded. Thus, although 10 acres (0.04 km²) on the mainland and Flinders Island support the same number of species, a mainland area of the same size as Flinders Island supports about twice as many species (Fig. 2). Similarly, 10 acres (0.04 km²) at Creswick supports about twice as

many species as 10 acres in Tasmania, but an area in Victoria of the size of Tasmania would contain nearly three times the number of species (Fig. 2).

MacArthur (1969) plotted numbers of species in tropical and temperate areas against area, and found that the tropical line rises more quickly for large areas (> 260 km²) than does the temperate line, so paralleling the result for mainland and island lines in Fig. 2. He concluded this meant tropical bird species have rather more finely subdivided their habitat relative to temperate species. This, however, may be more of an effect than a cause. Tropical areas have a great diversity of insect and plant species and hence of habitat types, which might cause bird species to show

narrow habitat preferences. An analogous explanation might apply to mainland and island areas. Another factor which is probably of importance on mainlands is that species there can be rarer without becoming permanently extinct, as can happen on islands. On the mainland, any extinction of a species in an area can be made good by continual re-invasion from surrounding habitats.

This last idea is well exemplified by comparing small islands which have no species with 10 acre (0.04 km²) plots on larger islands. A 10 acre plot on Clifty Island or the Moncoeur Islands has no species of birds, whereas 10 acre plots on Deal, King, Flinders or Maria Island, Tasmania, or Creswick will have up to about 13 species (Fig. 2). This discrepancy is easily explained, because Clifty Island and the Moncoeur Islands (as well as most of the islands smaller than 4 km²) have no *Eucalyptus* habitats for bird species to live and breed in. However, an island such as Rodondo, which is small but well vegetated with *Eucalyptus* and *Melaleuca* forest, has (probably) only one species breeding. Yet it has a planar area 29 times that of a 10 acre plot on the islands mentioned above.

This suggests that a 290 acre (1.17 km²) island, no matter how well vegetated, runs down with time. By virtue of its isolation, once it loses a species it is unlikely to regain it (or another). On the other hand, a 10 acre plot on a larger island is rather like a sample of the surrounding hospitable habitat. Any extinctions in a 10 acre plot are only temporary because they can be made good by invasion from the surrounding habitat.

Hence possibly for the species studied here, immigration and invasion rates onto islands are very low. On this hypothesis, many species are absent from the suitably vegetated Bass Strait islands because they cannot cross stretches of water sufficiently often or in numbers large enough to produce a viable population, and not because of ecological deficiencies on any islands. The best proof of this comes when species are deliberately introduced by man. This has not yet been done for any of the passerines studied here. However, it has been done with the Kookaburra (*Dacelo novaeguinae*) and Lyrebird (*Menura novaehollandiae*) into Tasmania (Abbott 1972 for details), and the Eastern Rosella (*Platycercus eximius*) onto Maria Island (J. H. Hemsley, pers. comm.). Such introductions have been successful because they remove the accidental nature of most movement of land bird species across stretches of water.

DISTRIBUTION AND ABUNDANCE OF LAND BIRD SPECIES

The pattern of the distribution of land bird species among the islands of Bass Strait and Tasmania and nearby Southern Victoria is markedly similar to that obtained for Amphibia (Littlejohn and Martin 1965) and Reptilia (Rawlinson 1967). Ornithologists (e.g. Lack 1970) have thought that the ability of birds to fly gives them exceptional powers of distribution.

Data on the distribution and abundance of bird species has been derived from Wheeler (1967) and from personal observations for Southern Victoria, from Green (1969), Green and McGarvie (1971) and personal observations for the Bass Strait islands, and from Sharland (1958) and personal observation for Tasmania. These are summarized in Appendix Tables 1 A-D. Because Tasmania has been well watched ornithologically for over a century, the literature was searched to see how often Victorian land bird species not today found breeding on the islands and Tasmania have been recorded from there. Standard authorities consulted were Gould (1848), Ewing (1842, 1855), Legge (1887, 1902), Campbell (1900), North (1901-1914), Littler (1910), Sharland (1958) and Newman (1971), as well as the *Tasmanian Journal of Natural Science* 1842-1849, *Papers and Proceedings of the Royal Society of Tasmania* 1851—present, and *Emu seriatim* (1901 onwards).

The distribution of species in Appendix Tables 1C and D falls into a relict pattern, suggesting an original widespread distribution of these species over Tasmania (s.l.), followed by differential extinction on all or some of the islands. Similar patterns exist for Amphibia (Littlejohn and Martin 1965), Reptilia (Rawlinson 1967), Mammalia (Hope 1969) and species of *Eucalyptus* (Abbott, unpubl. notes). On the other hand, 24 species of Southern Victorian land birds are unknown on the Bass Strait islands and Tasmania (Appendix Table 1E). Another 19 species are rarely recorded from these islands, except three that regularly breed on King Island (Appendix Table 1F). Eight other species, which are only vagrant to Southern Victoria, have been noted less than five times for Tasmania. Only one of these has been noted on the Bass Strait islands (Appendix Table 1G).

These distributional facts can be explained most simply by assuming these 51 species were not present in Southern Victoria when the Bass Strait landlink was last present. In the biogeographical studies of amphibians and reptiles cited above, species that today are found in Southern Victoria

but not in Tasmania and the Bass Strait islands have been called 'postglacial intrusives'. That is, the climatic conditions on the mainland at the time of isolation of these islands has largely determined which species were present on the islands (cf. Main 1961). This concept explains very well the distribution patterns summarized in Appendix Tables 1E-G.

It cannot be doubted that islands are not perfectly isolated from mainland areas, in the sense that there is movement of some species to and from (Appendix Tables 1F and G). This fact raises the question of why such species do not establish themselves. Lack (1971) stressed that birds wander more widely and more often than previously thought and that arrivals to islands are excluded by superior competitors already present. He writes '... any arrival [to a remote island] must compete immediately with the established species, and if it fails dies out' (Lack 1971:60; cf. Lack 1969:48). While it is true that most colonizing episodes do fail, it is not necessary to invoke competitive exclusion to explain why the arrivals do not establish themselves. Movement of most land birds across stretches of water is spasmodic and casual (as exemplified by evidence in Appendix Tables 1F and G), so that too few individuals of a species arrive at any one place or time on an island. Any invasion, to be successful, must involve at least one male and one female which must stay on the island and meet in the breeding season. Even species that migrate from northern Australia to Victoria in Spring have only rarely been recorded from the Bass Strait islands and Tasmania (Appendix Table 1F). Indeed, there are still many species that have not been recorded from Tasmania after 100 years of watching (Appendix Table 1E).

Conversely, if any of the 13 species endemic to the Tasmanian region have strayed in significant numbers to Southern Victoria (which is well watched by ornithologists), there should be records for these in the literature. Yet, only two (unconfirmed) sight records are known. These are *Anthochaera paradoxa*, one bird, recorded at Somers, 1951 (Reid 1967) and *Strepera fuliginosa*, one bird, at Orbost (Wakefield 1958b). Records of doubtful authenticity for two other species are discussed by Wakefield (1958a). These records are another successful test of the hypothesis of just how slight over-water movement of most land birds is.

Apparently suitable habitat exists on Tasmania and the large Bass Strait islands for most of the species listed in Appendix Tables 1E and F. Carefully managed introduction of these species

onto the islands should establish the species, as happened for the Kookaburra and Lyrebird in Tasmania, and the Eastern Rosella on Maria Island.

A simple model accounting for the distribution patterns of land bird species on the Bass Strait islands and Tasmania can now be sketched. Twelve species are members of double or triple invasions and double colonizations (Appendix Tables 1A and B), and have evolved through the make-and-break connexions across Bass Strait as sealevel fell and rose throughout the Pleistocene. If during the make-connexions *Eucalyptus/Acacia* vegetation covered Bass Strait, there would have been no physical barrier to movement of bird populations along the Tasmanian peninsula, although climatic effects could have affected any movement. Probably the avifaunas of Tasmania and Southern Victoria at these times intermixed. At the close of the last glacial, the species listed in Appendix Tables 1A-D became isolated on Tasmania, the Bass Strait islands, and Victoria. In some cases, extinction of some or all island populations followed, or surviving populations became subspecifically distinct (Abbott, unpubl.) as a result of reduction of any large scale movements between surviving populations. Since the landlink was last broken, and following mainland climatic changes, many land species (Appendix Tables 1E-G) moved into Southern Victoria, but were prevented from moving south by Bass Strait.

Although this scheme is admittedly speculative in parts, it should serve as a tentative framework in which to make finer analyses of the evolution of the avifaunas of the Bass Strait region.

FEEDING ECOLOGY OF SOME PASSERINE SPECIES

Currently, there are two views as to why island birds tend to undergo shifts in feeding zones and changes in feeding behaviour relative to their mainland representatives. First, following from an assumed general impoverishment of islands, shortage or unavailability of food may force many species to forage more widely. Such species differ from mainland equivalent species in where and how they seek their food (Keast 1968, 1970; Lack 1971). These 'generalists' are in such situations more successful than 'specialist' species, and are usually regarded as responsible for the latter being absent or rare (Lack 1971). A second view notes that islands always have far less breeding species than the mainland, so that those species present on an island can capitalize on this by foraging more widely (Grant 1965, 1966a; Mac-

Arthur et al. 1972, but see Morse 1971). Grant (1965) has also suggested that changes in lengths of bill and tarsus may be linked with increased ecological versatility of island bird species. The relationship between morphology and feeding behaviour of some passerine species on the Bass Strait islands, Tasmania and mainland Victoria is hence now examined.

In Tables 4-8, details of the morphology (length of bill, tarsus, hallux and wing) of males of each species are given. This information was derived by measuring all relevant material held in Australian collections. Sample sizes from Victoria and Tasmania for *Acanthiza*, *Sericornis*, *Acanthornis*, *Melithreptus* and *Meliphaga* are generally very much larger than those used by Keast (1968, 1970). Differences in bill length and hallux length between populations of the same species were tested using t-tests for statistical significance where sample sizes were large enough. Feeding behaviour was determined by following many individuals and timing their feeding from bark and foliage with a stopwatch, in the following areas: Deal Island, *Eucalyptus nitida* scrub in Lighthouse Gully; Flinders Island, *Eucalyptus globulus* and *E. viminalis* forest, and *Melaleuca ericifolia*/*Acacia melanoxylon* forest in Smiths Gully; King Island, *Eucalyptus globulus*/*E. viminalis*/*Melaleuca ericifolia* forest near Raffertys Gully; and Tasmania, *Eucalyptus tasmanica*/*E. linearis* forest on eastern side of Mt Louis; and Maria Island, *Eucalyptus obliqua*/*E. globulus* forest NE. of farm near Chinamans Bay. These feeding data have been grouped into categories, such as time spent foraging from bark and time spent gleaning leaves. I have used Keast's (1968, 1970) figures of foraging zonation for Victoria and Tasmania. Keast did not visit the Bass Strait islands, so that my data for three Bass Strait islands should also complement Keast's analysis of the Victorian and Tasmanian situation. In the Tables, I have included foraging data for Maria Island, although I have no morphological data for populations there.

These data are used here to test theories that have been proposed for the Tasmanian (Keast 1968, 1970) and other avifaunas (Grant 1968). Islands, for this purpose, can be treated as natural replicates where the relationship between feeding behaviour, morphology, and presence (or absence) of competitor species can be tested.

Acanthiza ewingi and *pusilla* (Table 4A, B)

The distribution and abundance of these *Acanthiza* species on the islands and Victoria have been summarized in Appendix Table 1A. *A.*

pusilla and *A. ewingi* live together on only two islands, namely King Island and Tasmania. *A. pusilla* is found alone on Deal Island (as well as Victoria), and *A. ewingi* alone on Flinders Island and Maria Island. On Tasmania, the species are well separated by habitat, with *A. pusilla* in drier habitats, and *A. ewingi* in gullies (Campbell 1905; Ridpath and Moreau 1966; pers. obs.). In Smiths Gully, Flinders Island, *A. ewingi* is very common in the vegetation lining the creek, but only vagrant individuals are found in the *Eucalyptus* forests on the slopes (pers. obs.). Near Raffertys Gully, King Island, *A. ewingi* is similarly most common close to the creek, and rare away from it (pers. obs.). On King Island, *A. pusilla* (of which only four specimens are known to exist, despite collecting in 1887, 1902, 1908, 1935, 1965 and 1968) was not observed during my stay there. However, Campbell (1903), who collected three of these specimens, reported it inhabiting 'the shorter scrub . . . away from the watercourses'. *A. pusilla* on Deal Island was common throughout the scrub and as there is little development of gully vegetation on the island, it is not surprising *A. ewingi* is absent. On mainland Victoria, *A. pusilla* is common in wet and dry forest (pers. obs.). These data show there is no consistent trend in habitat occupation between the two species in the different situations. Yet, current theory suggests species should expand their habitat when competitor species are absent (MacArthur and Wilson 1967). This was not observed.

When either *A. ewingi* or *A. pusilla* lives without the other, it is also predicted by current theory (e.g. Lack 1970, MacArthur and Wilson 1967) that their morphology and feeding behaviour should change. When *A. ewingi* is alone, it is predicted that bill and tarsal lengths will be different, as will feeding, from when *A. pusilla* is present. However, no significant differences between bill lengths and tarsal lengths were found between the Flinders Island and King Island populations of *A. ewingi*, although there is a highly significant difference in foraging zonation (Table 4B). The barkfeeding component in the ecology of *A. ewingi* on King Island is only minute, and yet *A. pusilla* there is exceedingly rare. The very long bill of *A. pusilla* on King Island suggests that it is an adaptation for probing bark. Green and McGarvie (1971) have suggested that on King Island *A. ewingi* is supplanting *A. pusilla*, and they have documented that *A. ewingi* today on King Island is more common than it was in 1887 and 1902. Although their explanation involving competitive exclusion seems

so plausible, my data (Table 4B) on the foraging of *A. ewingi* on King Island show that it does not feed from bark, which is where *A. pusilla* would be expected to feed. There are no records in the literature describing how *A. pusilla* on King Island feeds; but Keast (1970) has shown that the moderately longbilled *A. pusilla* in Tasmania has a strong barkprobing component in its feeding ecology. Thus, the existing data do not strongly support Green and McGarvie's hypothesis.

Although the bill length of *A. ewingi* on King and Flinders Island is intermediate between *A. ewingi* in Tasmania or *A. pusilla* in Victoria and *A. pusilla* in Tasmania, their feeding ecology as I have measured it is certainly not intermediate (Table 4). The plant species (*Eucalyptus*, *Melaleuca*) on which *Acanthiza* largely foraged are present on King and Flinders Islands, so there is no question of their habitat types differing between these islands.

Grant (1966b) has suggested that a long tarsus is mechanically useful to birds that use firm perches, such as thick branches, tree trunks, or the ground; and that a short tarsus is more advantageous when nonrigid (narrow) perches are used. On his hypothesis, individuals belonging to *A. ewingi* should more often forage on or near the ground or on the lower parts of trees, whereas *A. pusilla* should forage most often in the treetops (Table 4A). Also, *A. ewingi* on King and Flinders Islands should forage by gleaning leaves, whereas *A. ewingi* on Tasmania should be more of a barkprober (Table 4A). These predictions are falsified by data in Table 4B. More precise predictions can be made, as follow:

Because there is no significant difference in tarsal lengths between the King and Flinders Island populations of *A. ewingi*, there should be no difference in foraging zones. (False.)

Because there is no significant difference in tarsal lengths of *A. pusilla* in Tasmania and Victoria, there should be no difference in foraging zones. (False.)

Because *A. ewingi* on Tasmania has a significantly longer tarsus than *A. pusilla* on Tasmania or Victoria, it should feed from bark more than it does from foliage. This is true relative to *A. pusilla* in Victoria, but not so relative to *A. pusilla* in Tasmania.

There is thus no trend either way. Grant (1965) has also proposed that the longer bills and legs of island birds enhance their ecological versatility. In terms of the way I have measured feeding zonation, a completely versatile species should spend 50% of its feeding time probing bark, and 50% gleaning leaves and outerbranchlets for

food. The only populations of *Acanthiza* that remotely approach this condition are those of *A. pusilla* on Deal Island and Tasmania (Table 4B). However, time spent in feeding in each category for these islands is significantly different (X^2 test, 1 df).

Meliphaga flavicollis and *leucotis* (Table 5A, B)

M. flavicollis is the island representative (Table 1) of the mainland *M. leucotis*. The bill lengths (Table 5A) of *M. flavicollis* on King and Flinders Island and Tasmania are not significantly different, but each is significantly different from that of the Victorian *M. leucotis*. As expected, the island populations, with one inexplicable exception, spend more time feeding from bark. Although the bill lengths of *M. flavicollis* on King and Flinders Islands are not significantly different, the King Island population spends a disproportionate amount of its time feeding from bark (Table 5B). No reason can be suggested that might explain such a difference. The chief bark probing species on the mainland (treecreepers *Climacteris* spp. and sitellas *Neositta* spp.) are absent from the whole of the Tasmanian region, so this cannot explain the difference. The change cannot easily be attributed to differences in tarsal length, as hypotheses of Grant (1966b) and Keast (1968) might suggest. The King and Flinders Island populations do not significantly differ in tarsal length, and the other two populations are significantly different from these. That is, the order of tarsal length is Tasmania (largest); King and Flinders Islands; and Victoria (smallest). If tarsal length were the cause of differences in foraging among the populations, then these should feed from bark in the same order. This is clearly not so (Table 5B). If the island populations are ecologically more versatile than the mainland population, the proportion of feeding time allotted to the three categories should be more nearly equal, namely around 30%. This is not so for any population (Table 5B).

Melilireptus affinis and *lunatus* (Table 6A, B)

The islands on which these members of a superspecies are found are set out in Appendix Table 1A. Apparently, no specimens have been collected from Deal Island, but the species is rare there and I was unable to observe it enough to measure its foraging behaviour. (For the record, the 60 seconds that I watched it feeding were spent gleaning foliage and the outerbranchlets of *Eucalyptus*). The samples of *M. affinis* (Table 6A) from Flinders and King Islands are too small to treat statistically. However, the Victorian population has a significantly longer bill,

and a significantly shorter tarsus and hallux than the Tasmanian population. Foraging data for these populations (Keast 1968) show scarcely any difference, though *M. affinis* where I studied it in Tasmania spent over 30% of its foraging time probing bark (Table 6B). The island populations are somewhat more versatile than the mainland population (Table 6B), thus agreeing with the hypothesis of ecological release.

Melithreptus validirostris and *gularis*
(Table 7A, B)

M. gularis is only a vagrant south of the Great Dividing Range in Victoria (one record, Lower Glenelg 1958 (Learmonth 1966)); occasional records, You Yangs (Hore-Lacy 1959); one record, Somers (A. Reid pers. comm.); National Museum skins (one each) from Rockbank 1913, Chiltern 1900, Mt Macedon 1957; recorded at Bambra, c. 1900 (Hill 1903)). In contrast, *M. validirostris* is extremely abundant in *Eucalyptus* forest on King and Flinders Islands (pers. obs.) and Tasmania (Keast 1968; pers. obs.).

Because *M. validirostris* on the islands has a significantly longer tarsus and hallux than the mainland *M. gularis* (Table 7A), it would be expected to spend more of its time feeding from bark. This is confirmed by data in Table 7B. However it is not really more versatile in its feeding, because on King and Flinders Islands *M. validirostris* spends a disproportionate amount of its time feeding on bark. There is a real shift to feeding in almost a totally different zone on the islands (Table 7B), and not just diversification, as Keast (1968) incorrectly emphasized. Moreover, the King Island population of *M. validirostris* is significantly longer billed than the Tasmanian population, but is less versatile ecologically (Table 7B).

Acanthornis magnus, *Sericornis frontalis* and *humilis*
(Table 8A)

This, and the next case, are examples of species that differ significantly in morphology from isolate to isolate, but show scarcely any difference in foraging zonation. *Acanthornis* is sometimes treated as a species of *Sericornis* (e.g. Keast 1970). The distribution of the three species is outlined in Appendix Table 1A. *Sericornis frontalis* and *humilis* spend over 95% of their foraging time on the ground or within 2 m of the ground on islands and mainland. No times were recorded because *Sericornis* rarely feeds anywhere else (pers. obs.; R. Wheeler, pers. comm.). In my experience, *Sericornis* leaves this low zone only when disturbed by the observer. Yet, real differences in bill and tarsal length do exist (Table

8A). The Tasmanian population has the largest bill, though it is not significantly different from that of the Flinders Island population. The bill length of the Victorian population is significantly less than that for any other population. Also, the King Island and Tasmanian populations have larger tarsi than the Deal and Flinders Island populations. *Sericornis* in Victoria has a tarsal length significantly less than that of any other population, but shows no tendency to feed above the ground. Presumably there is some subtle ecological factor on the ground that is responsible for the morphological differences found.

Malurus cyaneus (Table 8B)

The King Island, Flinders Island and Tasmanian populations are significantly different in bill length and tarsal length from the mainland (Victorian) one. However, *Malurus* is primarily a ground feeder (pers. obs.), and shows no difference in foraging zonation on the islands. Populations with smaller tarsi (Victoria, smallest, and Tasmania) do not show a perceptible trend to feed away from the ground. Thus morphological differences do exist, but it is not possible to correlate them with any differences in foraging heights, or preferences for feeding from bark versus leaves, or increased variability of feeding heights. Ants predominate in the stomachs of *Malurus cyaneus* that have so far been collected on the mainland (Rowley 1965, p. 297) and King Island (Green and McGarvie, 1971, p. 40). However, any difference in size of ants on mainland and island is yet to be looked for.

This analysis of the feeding ecology of 11 species of passerines does not support current hypotheses concerning the inter-relationships of morphology, feeding stations, habitat occupation and competition. According to the theory of 'ecological release', bird species on species-poor islands should expand their feeding zones relative to the feeding zones of the same or similar species on mainlands. On Tasmania and the Bass Strait islands, the opportunity for such ecological broadening exists because of the numerical impoverishment of bird species or of the poor variety of habitats.

The numbers of breeding passerine species in Southern Victoria, Tasmania, Maria Island, King Island, Flinders Island and Deal Island are respectively 78, 47, 36, 37, 34 and 12. The numbers of *Eucalyptus* species (dominating the forest habitats on these islands) are respectively 32, 24, 6, 3, 5 and 1.

With the most comprehensive example (*Acanthiza*), for which there are seven populations available for consideration, there was no evidence

that either species occupied broader habitats when its competitor was absent. The evidence also showed there was no broadening of foraging zones of *A. ewingi* on King Island and Maria Island, but *A. pusilla* on Deal Island did exhibit wider choice in where it fed. No consistent correlation between bill and leg dimensions and feeding ecology was found.

With *Meliphaga leucotis* and *flavicollis*, the King and Flinders Island populations foraged more at bark than did the mainland *M. leucotis*, but did not broaden in their choice between feeding at bark or leaves. Populations of the *Melithreptus lunatus* superspecies were found to broaden their foraging zones only slightly, and on Tasmania and Maria Island foraging was most generalized. *M. validirostris* on islands switched its foraging zone to probing bark, while the mainland *M. gularis* chiefly gleaned leaves. The island populations showed little broadening in feeding zonation.

In spite of differences in length of bill and tarsus, island populations of *Sericornis* species fed chiefly on the ground, which is where mainland populations forage. There was no tendency for the populations on the island to forage from bark. Similar conclusions apply to *Malurus cyaneus*.

These data allow three conclusions. First, it is not possible to consistently correlate morphological traits of populations with their foraging traits, nor morphological differences between island populations with foraging differences. Second, there was little evidence that island populations are more versatile in their choice of foraging zones than mainland ones. Keast's (1968) hypothesis that the absence of mainland bark-probing bird species from Tasmania is responsible for some *Melithreptus*, *Acanthiza* and *Meliphaga* species there switching to exploit this niche seems only partially true. The Bass Strait islands also lack the mainland bark-probing species, but the percentage of time the *Melithreptus*, *Acanthiza* and *Meliphaga* species spend feeding from bark differs markedly between islands. This suggests that differences in availability and/or abundance of food supply within islands, rather than ecological release, are important.

These conclusions can be further tested by studying the foraging of passerine species over the whole year. They may also be extended by stomach analyses.

VARIATION IN BILL AND TARSAL LENGTHS OF PASSERINES

Grant (1971), assuming that intraspecific variation in tarsal and bill length is adaptive, raised the

question of whether morphological variation in island populations should be any different from that in mainland populations. Several theories have been advanced suggesting that there should be a difference, although each theory suggests a conflicting result. First, if the diversity of habitats and food types on islands is less than on the mainland (as is widely assumed, e.g. by MacArthur 1965, Grant 1968, Keast 1970), morphological variation should be reduced on islands. In contrast (Grant 1966a), islands almost always have a decreased diversity of competitor species (with similar diets) and predator species, so that a larger range of food sizes should be available. Selection would therefore deal more kindly with extremes than on the mainland. Thus, island species may be expected to show increased morphological variation. However, it may also be possible (M. Littlejohn, pers. comm.) that the species present in the low number of habitats on the island simply utilize the food made available by the absence of competitor species, and in this case no morphological differences would be evident.

Extensive series of museum material collected from the Bass Strait islands, Tasmania and Victoria are suitable for looking critically at these ideas. As already mentioned, the history of the Bass Strait region suggests that the populations on the islands are relict ones, thus ruling out any influence Founder effect might have in determining variability (see Power, 1971, who had to contend with this factor). An analysis of the variation in bill length and tarsal length among samples of *Malurus cyaneus*, *Sericornis frontalis* and *S. humilis*, *Acanthiza ewingi* and *A. pusilla*, *Meliphaga leucotis* and *M. flavicollis*, *Melithreptus lunatus* and *M. affinis*, and *M. gularis* and *M. validirostris* is presented in Appendix Tables 2A and B. Samples are compared using the ratio of squared coefficients of variation, and the significance of differences is tested by the variance-ratio test. Lewontin (1966) has shown that the variance of logarithms of measurements is a measure of variability which does not change multiplicatively, and that an approximation to this measure is the squared coefficient of variation $(s/\bar{x})^2$. Most of my sample sizes are relatively large compared with Grant's (1971), nearly all of whose sample sizes range from 5-10.

Of the 46 statistical comparisons made of bill length variability, only 6 cases gave significant differences between mainland and island samples (Appendix Table 2A). It is to be expected that, due to chance, about 5% of these 46 comparisons would be significantly different. However, a χ^2

test of the null hypothesis confirms there is no real difference in variability of bill lengths between islands and mainland (Table 9A). The island populations were more variable than the mainland populations in 5 out of the 6 instances of significant differences. Numbers are too small to allow this to be tested statistically. Forty-six comparisons of variability of tarsal lengths were also made between island and mainland populations. Of these, 14 gave significant differences between samples. A X^2 test for a 1:1 hypothesis shows that this difference is significant (Table 9B). That is, there is no real difference in variability in tarsal lengths between island and mainland populations (Table 9B). In four of the 14 significant cases the island population has the more variable tarsal length. A test of the significance of this is shown in Table 9C.

It is concluded from these data that the hypothesis of no real differences in variability of bill and tarsal lengths between island and mainland populations should be accepted. This supports the conclusions of similar analyses published by Grant (1967, 1971). There is, however, one important caveat in this type of analysis, pointed out by Van Valen (1965). He argued that when a mainland sample was gathered over a larger area than the island area, the variability of the mainland sample would increase such that many comparisons between island and mainland samples would be (erroneously) deemed nonsignificant. This seems a valid objection, since King and Flinders Island samples have been gathered over a much smaller area than has the Victorian sample (Abbott 1972, Appendix 3). However, the strength of the objection can be tested by comparing variabilities between Victorian and Tasmanian samples. These have been gathered over approximately the same sized area (see maps in Abbott 1972). Twelve comparisons are possible each for bill length and tarsal length variability. Comparisons were made by counting the number of cases in which the Victorian sample had the greater CV^2 , and the results were tested by the X^2 method (Table 9 D, E). No significant difference in variability between the Victorian and Tasmanian samples was found.

Two current hypotheses (the 'niche-variation' model of Van Valen and Grant, and that of Soule and Stewart (1970)), attempt to explain why island populations should show a higher variability in phenetic characters than mainland populations. The niche-variation model states that individuals of a species in a region with great variety of resources and habitats will have narrow niches, and the population will exhibit low vari-

ability in, for example, bill and tarsal lengths. In particular, species on islands and in temperate areas should show increased variation relative to species on mainlands or in the tropics. Soule and Stewart (1970) postulated instead that any increased variability in island populations is the result of a transient release of variation, possibly due to a breakdown in canalization, rare phenotypes having a selective advantage, or to occasional arrivals of mainland individuals onto islands.

My analysis tests whether there should be any change in variabilities between islands and mainland areas. It does not uphold the hypothesis that island populations do have more variable bills and tarsi. Willson (1969) tested whether temperate species have more variable bill dimensions than did tropical species, and found no tendency for temperate species to be more variable.

Grant (1971) argued that the Van Valen-Grant model could be tested by seeing how the foraging behaviour of species showing inter-regional differences in variability of tarsal length compared. As shown before (Table 4B), *Acanthiza ewingi* on King and Flinders Islands have very different foraging behaviours, yet they show no significant difference in variability of tarsal lengths (males or females, Appendix Table 2B). Comparison of the data in Tables 4-8 and Appendix Tables 2A and B shows the above example is not an isolated one. The Van Valen-Grant model is thus not supported by this study.

These results also bear on a question raised by Sheppard et al (1968), namely whether individual birds on islands expand their range of habitats, or whether each individual is as restricted as ever but more kinds of individuals are present. My data on tarsal and bill length variability do not support their second alternative.

Variability in bill and tarsal lengths could be determined selectively as follows. Selection could act on bill or tarsal length, on total body size, or on some other body part with which bill or tarsal length is correlated genetically (Grant 1971). For the species studied in this section, I tested to see whether bill or tarsal length were correlated with wing length (used as an indicator of body size). The significance of data are analysed in Table 10. Tarsal length is highly significantly correlated with wing length (Table 10B), but bill length is not significantly correlated with wing length (Table 10A). This suggests that if variation in wing length could be explained, most of the variation in tarsal length would automatically be explained. (However, Grant (1971) found the opposite for species from the Tres Marias Islands

and nearby Mexico). This is not an appropriate explanation for variation in bill length, so that one (or both) of the other modes of selection is (or are) responsible.

Neither of the predictions of the two theories outlined in the introduction of this section hold for the group of eleven passerine species studied here. This was unexpected, since the basic assumptions and arguments of these theories seem intuitively correct. The results of my analyses are, however, consistent with Littlejohn's suggestion (above). Other evidence from an analysis of variability of beak dimensions in finches on the Galapagos Islands (Abbott 1972 and unpubl.) similarly does not support either theory. These theories, in spite of their superficial attractiveness, need revising. This is in accord with other arguments put forward by Abbott (1972).

CONCLUSIONS

1. An exposed Bass Strait during the last glacial may have been important in the evolution and ecology of the bird species which are today restricted to the Tasmanian region. Compared with other Australian continental islands, islands in the Tasmanian region have a high percentage (up to 17%) of their avifauna not found on mainland Australia. With the available data, it is not possible to sort out isolation by distance, and isolation during time, as explanatory factors.

2. Numbers of forest passerine species on the Bass Strait islands and Tasmania when plotted against their area do not satisfactorily fit the standard exponential species/area curve. Relative to mainland Victoria, these islands have a depauperate passerine component in their avifaunas.

3. When Bass Strait was last flooded, the islands so formed acted virtually as closed systems, in that many species so isolated have since become extinct and most mainland species have been unable to invade. The pattern of distribution of species is largely relict. Fifty-one species of land birds in Southern Victoria apart from three breeding on King Island are accidental or unknown from Tasmania and the Bass Strait islands. These are probably postglacial intrusives into Southern Victoria.

4. It is not necessary to invoke competitive exclusion to explain why Tasmania and the Bass Strait islands have species-poor avifaunas. Extralimital records of mainland species of land birds are scarce, and this is not entirely due to a lack of observers on the islands.

5. Quantitative data on the feeding ecology of eight passerine species indicate there is no

consistent correlation of beak and leg dimensions with time spent feeding from bark and leaves. There was little evidence for ecological release with relaxed competition on the Bass Strait islands and Tasmania.

6. No significant differences in variation in bill length and tarsal length were found for populations of eleven passerine species on the Bass Strait islands, Tasmania and Victoria. The generally accepted theory of competition would have predicted otherwise.

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TABLE 1
DISTRIBUTION OF BIRD SPECIES ENDEMIC TO TASMANIA REGION

| Species on Tasmania | On other islands |
|---|-----------------------------------|
| <i>Tribonyx mortierii</i> , Tasmanian native hen | King, Deal, Flinders, Cape Barren |
| <i>Platycercus caledonicus</i> , Green Rosella | King, Flinders, Cape Barren |
| <i>Acanthiza ewingi</i> , Ewing's Thornbill | King |
| <i>Acanthornis magnus</i> , Scrubtit | King, Flinders, Cape Barren |
| <i>Sericornis humilis</i> , Brown Scrubwren | King, Flinders, Cape Barren |
| <i>Petroica vittata</i> , Dusky Robin | King (?still), Flinders |
| <i>Pardalotus quadragintus</i> , Forty spotted Pardalote | King, Flinders, Cape Barren |
| <i>Melithreptus affinis</i> , Black headed Honeyeater | King, Flinders, Cape Barren |
| <i>M. validirostris</i> , Strong billed Honeyeater | King, Flinders, Cape Barren |
| <i>Meliphaga flavicollis</i> , Yellow throated Honeyeater | King, Flinders, Cape Barren |
| <i>Anthochaera paradoxa</i> , Yellow wattle bird | King |
| <i>Strepera arguta</i> , Clinking Currawong | King, Flinders, Cape Barren |
| <i>S. fuliginosa</i> , Black Currawong | King, Flinders, Cape Barren |
| Species endemic to islands alone (not on Tasmania) | |
| <i>Dromaius ater</i> , King Island Emu | King (extinct) |

NOTES: 1. Information from Green (1969, 1971) and Green and McGarvie (1971), and personal observation on all islands excluding Cape Barren, for which Milledge (unpubl. lists) and Whinray (1970). 2. *Lathamus discolor*, Swift Parrot has been wrongly treated as endemic to Tasmania by past workers (Abbott and Milledge, in press).

TABLE 2
PERCENTAGES OF TASMANIAN REGION ENDEMIC SPECIES ON
TASMANIA AND BASS STRAIT ISLANDS
(TOTAL NUMBER OF SPECIES ON EACH ISLAND IN PARENTHESES)

| Group | Tasmania | King I. | Flinders I. | Cape Barren I. | Deal I. | Authority |
|-------------------|----------|---------|-------------|----------------|---------|---|
| Mimosaceae | 11 (18) | 0 (8) | 0 (16) | 0 (7) | 0 (3) | J. H. Willis, unpubl. list; Curtis (1956); P. A. Barnett, unpubl. list. |
| Myrtaceae | 33 (45) | 0 (9) | 0 (21) | 0 (11) | 0 (7) | Willis and Barnett |
| <i>Eucalyptus</i> | 46 (24) | 0 (3) | 0 (5) | 0 (5) | 0 (1) | Willis and Barnett, Curtis (1956); Pryor and Johnson (1971) |
| Proteaceae | 54 (24) | 0 (2) | 18 (11) | 25 (8) | 0 (1) | Willis, Barnett, Curtis (1967) |
| Epacridaceae | 62 (72) | 0 (10) | 0 (21) | 0 (11) | 0 (5) | Willis, Barnett, Curtis (1963) |
| Mosquitoes | 7 (30) | 0 (10) | 0 (22) | ? | 0 (3) | Dobrotworsky (1966) |
| Amphibians | 20 (10) | 0 (6) | 0 (6) | ? | 0 (0) | Littlejohn and Martin (1965); Littlejohn (pers. comm.) |
| Reptiles | 14 (14) | 11 (9) | 16 (12) | ? | 0 (6) | Rawlinson (1967) and pers. comm.; Green and McGarvie (1971) |
| Birds | 12 (104) | 17 (72) | 12 (73) | 13 (c.60) | 6 (18) | see Table 1, note |
| Mammals | 13 (31) | 0 (14) | 0 (18) | ? | 0 (2) | Hope (1969) |

TABLE 3
 ENDEMIC BIRD SPECIES ON AUSTRALIAN ISLANDS

| Island | Nearest mainland point(s) | Minimum distance km | Area km ² | Height m | Approx. depth of Strait at which island separates from mainland (m) | When isolated (years BP) | Number of bird species not shared with mainland | Number of bird species restricted to island |
|------------------------|--------------------------------|---------------------|----------------------|----------|---|--------------------------|---|---|
| King | Cape Otway, Vic. | 89 | 1,100 | 210 | 72-81 | 16000 | 12 [♂] | 1 |
| *Deal | Wilson's Promontory Vic. | 89 | 12 | 285 | 54-60 | 13000-14000 | 1 | 0 |
| *Flinders | Wilson's Promontory Vic. | 139 | 1,300 | 750 | 54-60 | 13000-14000 | 9 | 0 |
| *Cape Barren | Wilson's Promontory Vic. | 210 | 470 | 680 | 54-60 | 13000-14000 | 8 | 0 |
| *Tasmania | Wilson's Promontory Vic. | 240 | 62,000 | 1,590 | 54-60 | 13000-14000 | 13 | 2 |
| Kangaroo | Capes Jervis and Spencer, S.A. | 13,45 | 4,350 | 295 | 28-36 | 10000-11000 | 1 (extinct) | 1 |
| Rottneest | Fremantle, W.A. | 18 | 19 | 39 | 9 | 6000-7000 | 0 | 0 |
| Houtman Abrolhos | Geraldton, W.A. | 57 | 10 | 15 | 36-45 | 11000-12000 | 0 | 0 |
| Dirk Hartog | Edel Land, W.A. | 3.2 | 640 | 182 | 7.5 | 6000 | 1 [♂] | 0 |
| Dorre | Carnarvon, W.A. | 55 | 47 | 45 | 15 | 8000 | 0 | 0 |
| Bernier | Carnarvon, W.A. | 47 | 45 | 51 | 16 | 8000 | 0 | 0 |
| Barrow | N.W. Australia | 64 | 220 | 81 | 12 | 7000 | 1 [♂] | 0 |
| *Melville | Darwin area, N.T. | 24 | 5,700 | 104 | 18-36 | 8000-11000 | 0 | 0 |
| *Groote Eylandt | E. Arnhem Land, N.T. | 42 | 2,500 | 210 | 18-21 | 8000-9000 | 0 | 0 |
| *Torres Strait islands | Cape York, Qd | 29-57 | variable | | 9 | 6000-7000 | 0 | 0 |
| Fraser | Inskip Point, Qd | < 2 | 1,600 | 235 | 0.3-9 | <6000 | 0 | 0 |
| Moreton | Brisbane area, Qd | 23 | 160 | 275 | < 12 | <7000 | 0 | 0 |
| *North Stradbroke | Brisbane area, Qd | 5 | 320 | 215 | 0.3-1.5 | <1000 | 0 | 0 |

* with islands intervening

♂ one of these, and possibly another, now extinct (see notes, Table 1)

♂ endemic to Barrow and Dirk Hartog Islands

Source: See Appendix 1 in Abbott (1972)

TABLE 4A, B

A MORPHOLOGY OF *ACANTHIZA* SPECIES (means in mm).

| <i>A. ewingi</i> ♂ | Bill | Tarsus | Hallux | Wing | N |
|---------------------|------|--------|--------|------|-------------------|
| Tasmania | 11.8 | 21.4 | 7.8 | 54.6 | 37 |
| King Island | 12.3 | 20.4 | 7.6 | 53.9 | 16 |
| Flinders Island | 12.4 | 20.6 | 7.8 | 52.2 | 9 |
| <i>A. pusilla</i> ♂ | | | | | |
| Tasmania | 13.1 | 19.3 | 8.1 | 54.6 | 29 |
| King Island | 15.8 | 19.0 | 8.6 | 53.0 | 3 |
| Deal Island | 13.9 | 22.5 | 8.1 | 58 | 1 (live specimen) |
| Victoria | 11.7 | 19.8 | 7.4 | 51.7 | 30 |

B FEEDING ECOLOGY (%)

| | <i>A. pusilla</i> | | | <i>A. ewingi</i> | | | |
|-----------------------------|-------------------|-----------|-----------|------------------|------|-------------|----------|
| | Deal I. | Tasmania* | Victoria* | Tasmania* | King | Flinders I. | Maria I. |
| bark | 65 | 41 | 11 | 16 | 0.5 | 21 | 4.5 |
| outerbranchlets/ foliage | 35 | 66 | 87 | 82 | 99.5 | 79 | 95.5 |
| N | 1040 | 1078 | 1265 | 598 | 2975 | 7689 | 440 |

* From Keast (1970). His N = total no. feeding actions; My N = total no. seconds feeding.

TABLE 5A, B

A MORPHOLOGY OF *MELIPHAGA* SPECIES (♂, means in mm)

| | Bill | Tarsus | Hallux | Wing | N |
|---|------|--------|--------|-------|----|
| Victoria (<i>M. leucotis</i>) | 20.2 | 23.4 | 11.7 | 97.7 | 31 |
| King Island (<i>M. flavicollis</i>) | 21.6 | 25.1 | 13.4 | 106.1 | 9 |
| Flinders Island (<i>M. flavicollis</i>) | 21.7 | 24.6 | 13.2 | 105.1 | 8 |
| Tasmania (<i>M. flavicollis</i>) | 21.5 | 25.6 | 13.6 | 106.1 | 50 |

B FEEDING ECOLOGY (%)

| | Victoria* | King I. | Flinders I. | Tasmania* | Tasmania | Maria I. |
|-----------------------------|-----------|---------|-------------|-----------|----------|----------|
| lower trunk | 25 | 12 | 4 | 10 | 3 | 0 |
| upper trunk and branches | 10 | 61 | 47 | 36 | 29 | 56 |
| outerbranchlets and foliage | 65 | 28 | 49 | 55 | 71 | 44 |
| N | 1170 | 1625 | 533 | 1350 | 392 | 784 |

* From Keast (1968). His N = total no. feeding actions; My N = total no. seconds feeding.

TABLE 6A, B

A MORPHOLOGY OF *MELITHREPTUS LUNATUS* SUPERSPECIES (♂, means in mm)

| | Bill | Tarsus | Hallux | Wing | N |
|---------------------------------------|------|--------|--------|------|----|
| Victoria (<i>M. lunatus</i>) | 15.4 | 17.3 | 8.2 | 77.0 | 24 |
| King Island (<i>M. affinis</i>) | 14.4 | 18.9 | 8.6 | 78.2 | 5 |
| Flinders Island (<i>M. affinis</i>) | 15.0 | 19.0 | 9.0 | 76.0 | 3 |
| Tasmania (<i>M. affinis</i>) | 15.0 | 19.1 | 8.9 | 78.5 | 44 |

B FEEDING ECOLOGY (%)

| | Victoria* | King I. | Flinders I. | Tasmania* | Tasmania | Maria I. |
|-----------------------------|-----------|---------|-------------|-----------|----------|----------|
| lower trunk and ground | 0 | 0 | 0 | 0 | 7 | 2 |
| flowers | 0 | 12 | 2 | 0 | 4 | 0 |
| upper trunk | 0 | 0 | 2 | 0 | 0 | 5 |
| branches | 5 | 0 | 16 | 5 | 24 | 35 |
| outerbranchlets and foliage | 97 | 88 | 80 | 98 | 65 | 59 |
| N | 680 | 480 | 2628 | 1579 | 2118 | 1206 |

* From Keast (1968). His N = total no. feeding actions; My N = total no. seconds feeding.

TABLE 7A, B

A MORPHOLOGY OF *MELITHREPTUS GULARIS* SUPERSPECIES (♂, means in mm)

| | Bill | Tarsus | Hallux | Wing | N |
|---|------|--------|--------|------|----|
| Victoria (<i>M. gularis</i>) | 16.6 | 19.2 | 9.9 | 90.0 | 6 |
| King Island (<i>M. validirostris</i>) | 21.5 | 20.3 | 11.0 | 83.7 | 11 |
| Flinders Island (<i>M. validirostris</i>) | 20.7 | 19.7 | 10.5 | 80.7 | 3 |
| Tasmania (<i>M. validirostris</i>) | 20.0 | 20.8 | 11.1 | 82.8 | 22 |

B FEEDING ECOLOGY (%)

| | Victoria* | King I. | Flinders I. | Tasmania* | Tasmania | Maria I. |
|-----------------------------|-----------|---------|-------------|-----------|----------|----------|
| lower trunk | 2 | 95 | 29 | 5 | 45 | 0 |
| upper trunk and branches | 27 | 5 | 70 | 62 | 55 | 100 |
| outerbranchlets and foliage | 69 | 0 | 2 | 33 | 0 | 0 |
| N | 520 | 6965 | 7662 | 2250 | 595 | 98 |

* From Keast (1968). His N = total no. feeding actions; My N = total no. seconds feeding.

TABLE 8A, B

A MORPHOLOGY OF *SERICORNIS* SPECIES AND *ACANTHORNIS MAGNUS* (means in mm)

| | Bill | Tarsus | Hallux | Wing | N |
|---|------|--------|--------|------|----|
| Victoria (♂ <i>S. frontalis</i>) | 14.7 | 21.5 | 9.1 | 58.7 | 31 |
| King Island (♂ <i>S. humilis</i>) | 16.2 | 24.2 | 10.3 | 62.1 | 20 |
| Flinders Island (♂ <i>S. humilis</i>) | 16.5 | 23.0 | 10.0 | 60.7 | 18 |
| Deal Island (♂ <i>S. ?frontalis</i>) | 16.3 | 22.9 | 10.1 | 61.6 | 10 |
| Tasmania (♂ <i>S. humilis</i>) | 16.7 | 24.7 | 10.5 | 63.1 | 43 |
| Tasmania (unsexcd <i>A. magnus</i>) | 15.3 | 21.4 | 9.7 | 55.9 | 18 |
| King Island (unsexcd <i>A. magnus</i>) | 15.6 | 20.3 | 9.3 | 53.6 | 5 |

B MORPHOLOGY OF *MALURUS CYANEUS* (♂, means in mm)

| | Bill | Tarsus | Hallux | Wing | N |
|-----------------|------|--------|--------|------|----|
| Victoria | 9.0 | 22.3 | 8.1 | 52.4 | 54 |
| King Island | 9.9 | 24.0 | 8.7 | 54.9 | 28 |
| Flinders Island | 10.0 | 24.1 | 8.6 | 55.7 | 17 |
| Tasmania | 9.7 | 23.4 | 8.7 | 54.4 | 72 |

TABLE 9
X² TESTS

| | <i>No. instances</i> |
|--|----------------------|
| A. Comparison of differences in variability of bill length between islands and mainland No significant difference Significant difference X ² test of H ₀ , P < 0.001 | 40 6 |
| B. Comparison of differences of variability of tarsal length between islands and mainland No significant difference Significant difference X ² test of H ₀ , P < 0.01 | 32 14 |
| C. Comparison of differences in direction of variability of tarsal length between islands and mainland Island lengths sig. less variable Island lengths sig. more variable X ² test of H ₀ , P > 0.10 | 10 4 |
| D. Comparison of differences in variability of bill length between Victoria and Tasmania Variability of Victorian populations greater Variability of Tasmanian populations greater X ² test of H ₀ , P > 0.20 | 4 8 |
| E. Comparison of differences in variability of tarsal length between Victoria and Tasmania Variability of Victorian populations greater Variability of Tasmanian populations greater X ² test of H ₀ , P > 0.50 | 7 5 |

TABLE 10
X² TESTS

| | <i>No. instances</i> |
|--|----------------------|
| A. Comparison of significance of correlations between bill and wing lengths of 26 populations Significant correlation coefficient Nonsignificant r X ² test of H ₀ , P > 0.20 | 16 10 |
| B. Comparisons of significance of correlations between tarsal and wing lengths of 26 populations Significant r Nonsignificant r X ² test of H ₀ , P < 0.001 | 23 3 |

APPENDIX TABLE 1A-D

PATTERNS OF DISTRIBUTION AND ABUNDANCE OF BIRD SPECIES
ON TASMANIA, BASS STRAIT ISLANDS, AND SOUTHERN VICTORIA

| Species | Tasmania | King Island | Flinders Island | Deal Island | S. Victoria |
|--|----------|-------------|-----------------|-------------|-------------|
| A. Multiple invasions | | | | | |
| <u>Pardalotus quadragintus</u> | l.c | l.vr | l.r | - | - |
| <u>P. punctatus</u> | w.c | l.r | w.c | - | w.c |
| <u>Acanthiza ewingi</u> | w.a | w.a | w.a | - | - |
| <u>A. pusilla</u> | w.a | l.vr | - | w.a | w.a |
| <u>Acanthornis magnus</u> | w.c | l.r | - | - | - |
| <u>Sericornis humilis</u> | w.a | w.a | w.a | - | - |
| <u>S. frontalis</u> | - | - | - | w.a | w.a |
| <u>Melithreptus affinis</u> | w.a | l.r | w.a | - | - |
| <u>M. lunatus</u> | - | - | - | l.vr | w.a |
| <u>Platycercus caledonicus</u> | w.a | w.c | w.a | l.c | - |
| <u>P. elegans*</u> | - | - | - | - | w.a |
| B. Double colonization | | | | | |
| <u>Strepera fuliginosa</u> | w.a | w.c | w.a | - | - |
| <u>S. graculina</u> | - | - | - | - | w.a |
| <u>S. arguta</u> | w.a | - | - | - | - |
| <u>S. versicolor</u> | - | - | - | - | w.a |
| C. Species found in Tasmania and southern Victoria, but not on any Bass Strait island | | | | | |
| <u>Platycercus eximius</u> | l.c | - | - | - | w.c |
| <u>Cinclosoma punctatum</u> | w.c | - | - | - | w.a |
| <u>Acanthiza chrysorrhoa</u> | w.a | - | - | - | w.c |
| <u>Calamanthus fuliginosa</u> | w.c | - | - | - | l.c |
| <u>Stipiturus malachurus</u> | w.c | - | - | - | l.c |
| <u>Anthochaera chrysoptera</u> | l.c | - | - | - | l.c |
| <u>Manorhina melanocephala</u> | l.a | - | - | - | w.c |
| <u>Cracticus torquatus</u> | w.c | - | - | - | w.c |
| <u>Gymnorhina tibicen</u> | w.c | introduced | introduced | - | w.c |
| D. Species found in Tasmania and southern Victoria, and only some islands in Bass Strait (see also A above) | | | | | |
| <u>Malurus cyaneus</u> | w.a | w.c | w.c | - | w.a |
| <u>Petroica multicolor</u> | w.a | - | w.a | - | w.a |
| <u>Emblema bella</u> | l.c | - | l.c | w.c | w.c |
| <u>Phylidonyris novaehollandiae</u> | w.a | w.r | l.c | - | w.a |

Notation for A-D: w = widespread; l = localized; - = absent; a = abundant
c = common; r = rare; vr = very rare.

* Platycercus elegans also found on Rodondo Island (Bechervaise 1947)

APPENDIX TABLE 1E
SPECIES COMMON AND WIDESPREAD IN
SOUTHERN VICTORIA, BUT NEVER RE-
CORDED FROM TASMANIA OR BASS STRAIT
ISLANDS

Non-passerines

PSITTACIDAE

Glossopsitta porphyrocephala, Purple crowned Lori-
keet

Alisterus scapularis, King Parrot

ALCEDINIDAE

Dacelo novaeguinae, Kookaburra (Before 1900, see
text)

Passerines

MENURIDAE

Menura novaehollandiae, Lyrebird (Before 1934, see
text)

ACANTHIZIDAE

Acanthiza lineata, Striated Thornbill

A. nana, Little Thornbill

Hylacola pyrrhopygia, Chestnut tailed Groundwren

MALURIDAE

Dasyornis broadbenti, Rufous Bristlebird

MONARCHIDAE

Seisura inquieta, Restless Flycatcher

MUSCICAPIDAE

Microeca leucophaea, Jacky Winter

Eopsaltria australis, Yellow Robin

FALCUNCULIDAE

Falcunculus frontatus, Shrike-tit

Psophodes olivaceus, Eastern Whipbird

NEOSITTIDAE

Neositta chrysoptera, Sitella

DICAEIDAE

Pardalotus ornatus, Eastern Striated Pardalote

Dicaeum hirundinaceum, Mistletoe Bird

MELIPHAGIDAE

Meliphaga virescens, Singing Honeyeater

M. fusca, Fuscous Honeyeater

M. leucotis, White eared Honeyeater

M. melanops, Yellow tufted Honeyeater

M. penicillata, White plumed Honeyeater

Anthochaera carunculata, Red Wattle Bird

ESTRILDIDAE

Aegintha temporalis, Red browed Finch

PTILONORHYNCHIDAE

Ptilonorhynchus violaceus, Satin Bower Bird

APPENDIX TABLE 1F

SPECIES COMMON AND WIDESPREAD IN
SOUTHERN VICTORIA, BUT ACCIDENTAL
OR CASUAL TO TASMANIA AND BASS STRAIT
ISLANDS, *SPRING MIGRANTS TO SOUTHERN
AUSTRALIA.

Non-passerines

PSITTACIDAE

Trichoglossus haemotodus, Rainbow Lorikeet

TASMANIA: Ewing (1842) queries a specimen from
Swanport. Specimens shot 1871 (one near New Nor-

folk) and 1872 (Anon. 1872: 6, 50; 1873: 39), but
no details. No further records (Sharland 1958, New-
man 1971).

BASS STRAIT ISLANDS: No records, except for King
Island (one bird, 1966) (Green and McGarvie
1971).

Glossopsitta pusilla, Little Lorikeet

TASMANIA: Noted by Ewing (1842) for Maria Island,
and by subsequent cataloguers. Possibly resident,
though most reports are unconfirmed (Sharland
1958).

BASS STRAIT ISLANDS: No records.

Cacatua roseicapilla, Galah

TASMANIA: First record, no details (Anon. 1881: 3).
One pair, May 1908 (Littler 1910). Occasionally
since (Sharland 1958, Newman 1971). Some aviary
escapees (D. Milledge, pers. comm.).

BASS STRAIT ISLANDS: Odd birds occasionally on King
and Flinders Islands (Green 1969, Green and Mc-
Garvie 1971).

Callocephalon fimbriatum, Gang Gang Cockatoo

TASMANIA: First record, Circular Head (Ewing 1842);
occasional visitor since (Anon. 1853: 143; Sharland
1958).

KING ISLAND: Specimen collected 1802 (Stresemann
1951); Other records (Anon. 1874: 50, Campbell
1888, Anon. 1908: x, Green and McGarvie (1971)).
Probably resident there (Littler 1910).

No records for other islands.

ALCEDINIDAE

**Halcyon australiasiae*, Sacred Kingfisher

TASMANIA: First record, Southport (Anon. 1870: 7,
87). Also, Howrah (Anon. 1874: 9) and Cam-
bridge (Anon. 1886: cxlvii). Occasional records since
(Sharland 1958). No breeding records. Not regarded
as vagrant by Milledge (unpubl. 1970).

KING ISLAND: Campbell (1888); Green and McGar-
vie (1971).

DEAL ISLAND: Campbell (1891). No breeding records
for these islands.

No records for Flinders Island.

Passerines

HIRUNDINIDAE

**Petrochelidon ariel*, Fairy Martin

TASMANIA: First record, Bridport, about 1886, breed-
ing (Wintle 1887, but see Littler 1910). Not listed
by Legge (1902). One old nest, Tunbridge (Vincent
1968); One bird, near Hobart, October 1971 (Vincent
1972).

KING ISLAND: No records.

FLINDERS ISLAND: Recorded by Le Souef (1902),
though probably in error for *P. nigricans* (Tree Mar-
tin), which was not recorded.

CAMPEPHAGIDAE

**Lalage sueurii*, White winged Triller

TASMANIA: First listed (no details) by Campbell
(1900) and Legge (1902), although Littler (1910)
remarked, 'I am unable to discover how and when
this bird first came to be placed on the Tasmanian
list'. Subsequent records are Kelso, November 1912
(Littler 1913 and West Devonport, November 1916
(Dove 1917). Three birds near Devonport, November
1969, of which one pair bred (Pinner and Bird 1970).
KING ISLAND: Occasional (Green and McGarvie
1971).

FLINDERS ISLAND: No records.

SYLVIIDAE

Cisticola exilis, Tailor Bird

TASMANIA: First and only records, which are also breeding records, for Spring 1911-12 at Springfield (Fletcher 1913). These are discussed by Sharland (1972) and Courtney Haines (1972).

KING ISLAND: Breeding species (Campbell 1888, 1903; Green and McGarvie 1971).

No records for other islands.

RHIPIDURIDAE

**Rhipidura rufifrons*, Rufous Fantail

TASMANIA: First and only record (unconfirmed): one bird, Stanley, March 1945 (Sharland 1945).

No record for islands.

Rhipidura leucophrys, Willie Wagtail

TASMANIA: No published records.

KING ISLAND: Odd birds (Green and McGarvie 1971).

FLINDERS ISLAND: Odd birds (Green 1969; E. Warren pers. comm.).

MONARCHIDAE

**Myiagra rubecula*, Leaden Flycatcher

TASMANIA: First record Falmouth 1868 (Legge 1889); also Falmouth, February 1874 (Legge 1875). 'Regular visitor' (Littler 1910). Boat Harbour district (Fletcher 1918), though probably confused with *M. cyanoleuca* which was not listed. Unconfirmed sighting, November 1964 (Thomas 1965). First breeding record, January 1968 at Maria Island (Wall 1969).

KING ISLAND: no records.

FLINDERS ISLAND: Le Souef (1902), but not since.

PACHYCEPHALIDAE

**Pachycephala rufiventris*, Rufous Whistler

KING ISLAND: record occasionally (Green and McGarvie 1971).

No records for other islands.

CLIMACTERIDAE

Climacteris leucophaea, White throated Treecreeper

TASMANIA: Unconfirmed sight records, Quamby Bluff (Legge 1904) and near Wilmot (Fletcher 1908). Specimens allegedly collected by R. Gunn (Legge 1904).

No records for islands.

MELIPHAGIDAE

Meliphaga novaehollandiae, Yellow faced Honey-eater

KING ISLAND: Breeding species (M. McGarvie, pers. comm.). No other records.

Melithreptus brevirostris, Brown headed Honeyeater.

KING ISLAND: One specimen known (Mathews 1912; 394). Mathews took this specimen as representative of a King Island subspecies, an error which has been repeated by Cayley (1958) and Courtney (1963: 57).

Editor's Note: Since this table was compiled, the author informs me that he has seen the specimen on which this record is based and concludes that the bird must have been taken on Kangaroo Island not King Island (see Abbott's note in press, Emu Vol. 73).

GRALLINIDAE

Grallina cyanoleuca, Peewee

TASMANIA: First record, one pair at Stanley, July 1888 (Anon. 1889; xxxiii and North 1902: 89). Specimen collected at Spring Bay, April 1904 (Tas-

manian Museum). One bird near Triabunna, October 1969 (Milledge 1970). No breeding records (Sharland 1958).

KING ISLAND: Occasional (Green and McGarvie 1971).

FLINDERS ISLAND: Occasional (Green 1969; E. Warren, pers. comm.).

ARTAMIDAE

**Artamus personatus*, Masked Wood Swallow

**A. superciliosus*, White browed Wood Swallow

KING ISLAND: Occasional, although *A. superciliosus* turns up each year. There are no breeding records (Green and McGarvie 1971).

There are no records for other islands.

APPENDIX TABLE 1G

SPECIES ACCIDENTAL OR CASUAL TO
TASMANIA WHICH ARE ALSO ACCIDENTAL
OR CASUAL TO SOUTHERN VICTORIA.
ALL BUT ONE HAVE NOT BEEN
RECORDED FOR THE BASS STRAIT ISLANDS

Non-passerines

COLUMBIDAE

Ptilinopus regina, Red crowned Pigeon

TASMANIA: First record, Bothwell May 1922 (Lord and Arnold 1922). Also, Exeter, April 1968 (Green 1969). Individual birds only.

Ptilinopus superbus, Purple-crowned Pigeon.

TASMANIA: First record, Quamby about 1872 (Anon. 1873: 40). Also, Eddystone Point, April 1970 (Sharland 1970). Individual birds only.

Lopholaimus antarcticus, Topknot Pigeon

TASMANIA: First recorded by Ewing (1855). Also, N.E. coast, July 1907 (Littler 1910).

PSITTACIDAE

Nymphicus hollandicus, Cockatiel

TASMANIA: First record at Riversdale, about 1884 (Anon. 1885: lxix). Three subsequent records (Sharland 1958).

CUCULIDAE

Scythrops novaehollandiae, Channel billed Cuckoo

TASMANIA: First record, Clarence Plains about 1867 (Anon. 1868: 37). Also, near Launceston, February 1943 (Sharland 1943). Individual birds only.

CORACIIDAE

Eurystomus orientalis, Dollar Bird

TASMANIA: First confirmed record, Mt Jukes, about 1918 (Lord 1918). No subsequent records.

Passerines

DICRURIDAE

Dicrurus hottentotus, Spangled Drongo

TASMANIA: First record, Falmouth, May 1888 (Legge 1889). Subsequent records at Stanley 1888 and Bridport 1900 (Sharland 1958).

ARTAMIDAE

Artamus leucorhynchus, White breasted Wood Swallow

KING ISLAND: Occasional (Green and McGarvie 1971). No other records.

APPENDIX TABLE 2A

SIGNIFICANCE OF DIFFERENCES IN VARIATION IN BILL LENGTH BETWEEN ISLAND AND MAINLAND POPULATIONS. F VALUES ARE CALCULATED FROM SQUARED COEFFICIENTS OF VARIATION, AND THE LOCALITY WITH THE GREATER VARIANCE IS UNDERLINED

| Species | Localities | F (df) | P |
|---|---|---------------|----|
| <u>Malurus cyaneus</u> | ♂ <u>Victoria</u> x King Island | 1.69 (51,27) | ns |
| | ♂ <u>Victoria</u> x Flinders Island | 1.28 (51,16) | ns |
| | ♂ King Island x <u>Flinders Island</u> | 1.32 (16,27) | ns |
| | ♂ <u>Victoria</u> x <u>Tasmania</u> | 1.04 (51,65) | ns |
| | ♂ King Island x <u>Tasmania</u> | 1.63 (65,27) | ns |
| | ♂ Flinders Island x <u>Tasmania</u> | 1.23 (65,16) | ns |
| <u>Sericornis frontalis/</u> <u>humilis</u> | ♂ <u>Victoria</u> x King Island | 1.19 (30,19) | ns |
| | ♂ <u>Victoria</u> x Flinders Island | 1.14 (30,16) | ns |
| | ♂ King Island x <u>Flinders Island</u> | 1.05 (16,19) | ns |
| | ♂ <u>Victoria</u> x <u>Tasmania</u> | 1.08 (30,38) | ns |
| | ♂ King Island x <u>Tasmania</u> | 1.10 (38,19) | ns |
| | ♂ Flinders Island x <u>Tasmania</u> | 1.05 (38,16) | ns |
| | ♀ <u>Victoria</u> x King Island | 1.45 (15, 6) | ns |
| | ♀ <u>Victoria</u> x Flinders Island | 1.62 (15,11) | ns |
| | ♀ King Island x Flinders Island | 1.12 (6,11) | ns |
| | ♀ <u>Victoria</u> x <u>Tasmania</u> | 4.05 (15,14) | ** |
| | ♀ King Island x <u>Tasmania</u> | 2.79 (6,14) | ns |
| | ♀ Flinders Island x <u>Tasmania</u> | 2.50 (11,14) | ns |
| <u>Acanthiza ewingi</u> and <u>pusilla</u> | ♂ <u>Victoria</u> x <u>ewingi</u> King Island | 1.05 (29,14) | ns |
| | ♂ <u>Victoria</u> x <u>ewingi</u> Flinders Island | 2.34 (8,29) | * |
| | ♂ King Island x <u>ewingi</u> Flinders Island | 2.46 (8,14) | ns |
| | ♂ <u>Victoria</u> x <u>ewingi</u> <u>Tasmania</u> | 1.22 (35,29) | ns |
| | ♂ <u>Victoria</u> x <u>pusilla</u> <u>Tasmania</u> | 2.80 (27,29) | ** |
| | ♂ <u>ewingi</u> King Island x <u>ewingi</u> <u>Tasmania</u> | 1.29 (35,14) | ns |
| | ♂ <u>ewingi</u> Flinders I. x <u>ewingi</u> <u>Tasmania</u> | 1.91 (8,35) | ns |
| | ♀ <u>Victoria</u> x <u>ewingi</u> King Island | 1.37 (6, 6) | ns |
| | ♀ <u>Victoria</u> x <u>ewingi</u> Flinders Island | 1.54 (6, 5) | ns |
| | ♀ <u>ewingi</u> King I. x <u>ewingi</u> Flinders I. | 1.13 (6, 5) | ns |
| | ♀ <u>Victoria</u> x <u>ewingi</u> <u>Tasmania</u> | 1.02 (11, 6) | ns |
| | ♀ <u>Victoria</u> x <u>pusilla</u> <u>Tasmania</u> | 1.49 (17, 6) | ns |
| | ♀ <u>ewingi</u> King Island x <u>ewingi</u> <u>Tasmania</u> | 1.39 (11, 6) | ns |
| | ♀ <u>ewingi</u> Flinders I. x <u>ewingi</u> <u>Tasmania</u> | 1.57 (11, 5) | ns |
| <u>Meliphaga leucotis</u> and <u>flavicollis</u> | ♂ <u>Victoria</u> x King Island | 1.72 (8,29) | ns |
| | ♂ <u>Victoria</u> x Flinders Island | 1.33 (29, 6) | ns |
| | ♂ King Island x Flinders Island | 2.29 (8, 6) | ns |
| | ♂ <u>Victoria</u> x <u>Tasmania</u> | 2.18 (47,29) | ** |
| | ♂ King Island x <u>Tasmania</u> | 1.27 (47, 8) | ns |
| | ♂ Flinders Island x <u>Tasmania</u> | 2.90 (47, 6) | ns |
| | ♀ <u>Victoria</u> x King Island | 1.05 (16, 5) | ns |
| | ♀ <u>Victoria</u> x <u>Tasmania</u> | 1.42 (16,38) | ns |
| | ♀ King Island x <u>Tasmania</u> | 1.35 (5,38) | ns |
| <u>Melithreptus lunatus</u> and <u>affinis</u> | ♂ <u>Victoria</u> x <u>Tasmania</u> | 1.11 (42,23) | ns |
| | ♀ <u>Victoria</u> x <u>Tasmania</u> | 1.71 (22, 8) | ns |
| <u>Melithreptus gularis</u> and <u>validirostris</u> | ♂ <u>Victoria</u> x King Island | 2.16 (9, 5) | ns |
| | ♂ <u>Victoria</u> x <u>Tasmania</u> | 12.50 (21, 5) | ** |
| | ♂ King Island x <u>Tasmania</u> | 5.78 (21, 9) | ** |

Note: ns, *, ** respectively give the significance of a difference as $P > 0.05$, $0.05 > P > 0.01$, and $0.01 > P > 0.001$.

APPENDIX TABLE 2B

SIGNIFICANCE OF DIFFERENCES IN VARIATION IN TARSAL LENGTH BETWEEN ISLAND AND MAINLAND POPULATIONS. CONVENTIONS AS FOR APPENDIX TABLE 2A.

| Species | Localities | F (df) | P |
|---|---|--------------|----|
| <u>Malurus cyaneus</u> | ♂ <u>Victoria x King Island</u> | 1.42 (52,57) | ns |
| | ♂ <u>Victoria x Flinders Island</u> | 2.45 (52,16) | * |
| | ♂ <u>King Island x Flinders Island</u> | 1.72 (27,16) | ns |
| | ♂ <u>Victoria x Tasmania</u> | 1.27 (52,71) | ns |
| | ♂ <u>King Island x Tasmania</u> | 1.12 (71,27) | ns |
| | ♂ <u>Flinders Island x Tasmania</u> | 1.93 (71,16) | ns |
| <u>Sericornis frontalis</u> / <u>S. humilis</u> | ♂ <u>Victoria x King Island</u> | 3.17 (30,19) | ** |
| | ♂ <u>Victoria x Flinders Island</u> | 1.50 (30,17) | ns |
| | ♂ <u>King Island x Flinders Island</u> | 2.11 (17,19) | ns |
| | ♂ <u>Victoria x Tasmania</u> | 1.18 (42,30) | ns |
| | ♂ <u>King Island x Tasmania</u> | 3.74 (42,19) | ** |
| | ♂ <u>Flinders Island x Tasmania</u> | 1.77 (42,17) | ns |
| | ♀ <u>Victoria x King Island</u> | 2.86 (18, 6) | ns |
| | ♀ <u>Victoria x Flinders Island</u> | 1.59 (18,11) | ns |
| | ♀ <u>King Island x Flinders Island</u> | 1.79 (11, 6) | ns |
| | ♀ <u>Victoria x Tasmania</u> | 4.53 (18,15) | ** |
| | ♀ <u>King Island x Tasmania</u> | 1.59 (6,15) | ns |
| | ♀ <u>Flinders Island x Tasmania</u> | 2.85 (11,15) | * |
| <u>Acanthiza ewingi</u> and <u>pusilla</u> | ♂ <u>Victoria x ewingi King Island</u> | 3.08 (29,14) | * |
| | ♂ <u>Victoria x ewingi Flinders Island</u> | 6.02 (29, 8) | ** |
| | ♂ <u>ewingi King I. x ewingi Flinders I.</u> | 1.96 (14, 8) | ns |
| | ♂ <u>Victoria x ewingi Tasmania</u> | 5.90 (29,35) | ** |
| | ♂ <u>Victoria x pusilla Tasmania</u> | 3.34 (29,28) | ** |
| | ♂ <u>ewingi King Island x ewingi Tasmania</u> | 1.92 (14,35) | ns |
| | ♂ <u>ewingi Flinders I. x ewingi Tasmania</u> | 1.02 (35, 8) | ns |
| | ♀ <u>Victoria x ewingi King Island</u> | 5.93 (5, 6) | * |
| | ♀ <u>Victoria x ewingi Flinders Island</u> | 5.49 (5, 5) | * |
| | ♀ <u>ewingi King I. x ewingi Flinders I.</u> | 1.08 (5, 6) | ns |
| | ♀ <u>Victoria x ewingi Tasmania</u> | 3.77 (5,11) | * |
| | ♀ <u>Victoria x pusilla Tasmania</u> | 1.07 (5,16) | ns |
| | ♀ <u>ewingi King Island x ewingi Tasmania</u> | 1.57 (11, 6) | ns |
| | ♀ <u>ewingi Flinders I. x ewingi Tasmania</u> | 1.46 (11, 5) | ns |
| <u>Meliphaga leucotis</u> and <u>flavicolis</u> | ♂ <u>Victoria x King Island</u> | 1.25 (8,30) | ns |
| | ♂ <u>Victoria x Flinders Island</u> | 1.74 (7,30) | ns |
| | ♂ <u>King Island x Flinders Island</u> | 1.40 (7, 8) | ns |
| | ♂ <u>Victoria x Tasmania</u> | 2.04 (49,30) | ** |
| | ♂ <u>King Island x Tasmania</u> | 1.63 (49, 8) | ns |
| | ♂ <u>Flinders Island x Tasmania</u> | 1.17 (49, 7) | ns |
| | ♀ <u>Victoria x King Island</u> | 1.11 (8,15) | ns |
| | ♀ <u>Victoria x Tasmania</u> | 1.83 (39,15) | ns |
| | ♀ <u>King Island x Tasmania</u> | 9.03 (39, 5) | * |
| <u>Melithreptus lunatus</u> and <u>affinis</u> | ♂ <u>Victoria x Tasmania</u> | 1.50 (23,43) | ns |
| | ♀ <u>Victoria x Tasmania</u> | 1.38 (23, 9) | ns |
| <u>Melithreptus gularis</u> and <u>validirostris</u> | ♂ <u>Victoria x King Island</u> | 1.11 (5,10) | ns |
| | ♂ <u>Victoria x Tasmania</u> | 2.47 (21, 5) | ns |
| | ♂ <u>King Island x Tasmania</u> | 2.74 (21,10) | ns |

Note: ns, *, ** respectively give the significance of a difference as $P > 0.05$,
 $0.05 > P > 0.01$, and $0.01 > P > 0.001$.

A REVALUATION OF *Dasyurus bowlingi* SPENCER AND KERSHAW 1910 (MARSUPIALIA, DASYURIDAE) FROM KING ISLAND, BASS STRAIT

By L. G. MARSHALL* and J. H. HOPE**

ABSTRACT: A comparison of the subfossil crania and mandibles, on which *Dasyurus bowlingi* Spencer and Kershaw 1910 was erected, with modern and subfossil populations of *Dasyurus maculatus* (Kerr) 1792, leads to the conclusion that the two species are conspecific, and that *D. bowlingi* was described on a male sample of *D. maculatus*.

INTRODUCTION

In 1910 Spencer and Kershaw described a new species of tiger cat, *Dasyurus bowlingi*, from subfossil cranial material collected from King Island, Bass Strait. The dasyurid remains were found, associated with bones of emu, wombat and other modern species, in the calcareous coastal dunes at Surprise Bay on the southwestern corner of the island. In sorting the large dasyurid crania and mandibles, Spencer and Kershaw (1910, p. 30) stated that the material was 'clearly divisible into two sets, a larger and a smaller, indicating the existence of two species . . .'. They assigned the smaller form to *Dasyurus maculatus* and described the larger as *Dasyurus bowlingi*, which was distinguished by its narrower and less swollen auditory bullae as well as by its larger size in cranial and dental dimensions. As further evidence for their division of the subfossil cranial material into two species, Spencer and Kershaw also quoted Péron's record of the presence, in 1802, of two species of dasyurid on King Island (Péron and Freycinet 1816.)

Having compared the subfossil dasyurid specimens from King Island, including the holotype and paratype of *Dasyurus bowlingi*, with samples from modern Victorian and Tasmanian populations of *D. maculatus*, we conclude for reasons given below that *D. bowlingi* and *D. maculatus* are conspecific.

DISTRIBUTION

Dasyurus bowlingi has been recognised only

from King Island, though Spencer and Kershaw considered that a single mandible from Deal Island, in eastern Bass Strait, might also belong to this species. Tiger cats were last seen on King Island in 1923 and are thought to be now extinct. Modern specimens collected there have been attributed to *D. maculatus*, and Green and McGarvie (1971) list three skulls held in the Queen Victoria Museum, Launceston, (Nos. 1940/163, 1943/105 and 1967/1/59) and one skin in the National Museum of Victoria (No. C6139) as referable to this latter species. It has generally been assumed that *D. bowlingi* became extinct on King Island in the 19th century along with the emu and wombat, neither of which have been recorded alive there since Péron's report.

Gabriel (1894) included the tiger cat in a list of mammals of the Furneaux Group, and Le Soeuf (1929) stated that a native cat (*D. viverrinus*) was reported 'as still being seen on Flinders and [Cape] Barren Islands'. There are no other records of either species on the eastern islands, and there are apparently no museum specimens from these localities. However two mandibular fragments referable to *D. maculatus* have been recovered near Palana, Flinders Island, from coastal sand dunes which are similar to the dunes of King Island (Hope 1973). Apart from the islands of Bass Strait, *Dasyurus maculatus* occurs as a living species in Tasmania, Victoria, New South Wales and Queensland, possibly as far north as the Mellwraith Range (Tate 1952), and in the southeastern corner of South Australia (Wood Jones 1923-1925).

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It has been recorded fossil from Wellington Caves, New South Wales (Etheridge 1878) and in subfossil deposits from Victoria including Fern Cave near Portland; Mt Hamilton Cave; Bushfield, Tower Hill Beach and Swains Cave near Mt Porndon (Wakefield 1964a, 1967) and at Fromm's Landing rock shelter on the Lower Murray River (Wakefield 1964b). In McEacherns Cave *D. cf. D. maculatus* was found in the older 'Sthenurus Layer' in association with species of *Thylacoleo*, *Zygomaturus*, *Protemnodon*, *Sthenurus*, and *Sarcophilus laniarius* (Wakefield 1967). In Tasmania specimens were found in an aboriginal midden ^{14}C dated at 7080 ± 420 years B.P. (GaK-967) (Gill 1968). It is unknown from Western Australia. Marlow (1958) records it as preferring rain forest and sclerophyll forest.

PÉRON'S OBSERVATIONS

Although Spencer and Kershaw quoted Péron's comments on the fauna of King Island to justify their recognition of two large species of *Dasyurus* there, it is uncertain which species Péron actually saw. He reported (1816, Vol. 2, p. 12-13) that on King Island (November 1802): 'Nous y avons recueilli, M. Lesueur et moi, une foule d'espèce inconnues à l'Europe, parmi lesquelles se trouvent deux Dasyures élégans, . . .'.

At this point a marginal note refers to Plate XXXIII (our Fig. 1) in the first volume of the accompanying Atlas, compiled by Lesueur and Petit. This depicts two animals which are clearly *Dasyurus maculatus*. The same plate is again referred to when Péron comments on the fauna of Ile Decrès (Kangaroo I., S.A.) (January 1803): 'Nous y avons vu que trois espèces de mammifères: l'une appartient au joli genre des Dasyures' (*Ibid.* Vol. II, p. 76). As Plate XXXIII is mentioned only in connection with the faunas of King and Kangaroo Islands, and as the tiger cats are shown eating the carcass of a seal, circumstance likely on either island, the plate probably depicts a species which was seen by the Baudin expedition on one or both of these islands. However, one cannot place too much confidence in the juxtaposition of Plate XXXIII with the text, as Péron died in 1910, halfway through the compilation of Vol. II, which was completed by Freycinet.

The only other reference to a 'dasyure' made by Péron is where he notes (Vol. I, p. 359) that at Maria Island (27 February 1802): 'Dans la classe des mammifères, je n'ai pu voir qu'une seule espèce de Dasyure, de la grosseur à peine d'une souris'. This specimen was collected and is the

type of *Cercartetus nanus* (Desmarest) 1818 according to Wakefield and Warneke (1963). The Baudin expedition did in fact collect several other dasyurids that Péron does not mention, among them the type specimen of *Dasyurus macrourus* Geoffroy 1803, a junior synonym of *Dasyurus maculatus* (Kerr) 1792 (Tate 1947). The type locality of *macrourus* is Port Jackson.

There is no other evidence as to the identity of the 'deux dasyures' seen on King Island, and it is even possible that Péron meant nothing more than that two individual animals (as illustrated in Plate XXXIII) had been seen there.

MATERIAL

All specimens examined are from the collections of the National Museum of Victoria (NMV) unless otherwise indicated. Numbers preceded by the letter P are registered in the palaeontological collections, by C in the zoological collections.

Spencer and Kershaw recorded twenty-five crania and sixty mandibles in the collection they studied. Twenty-one of the crania were assigned to *D. bowlingi*, four to *D. maculatus*. As none of these specimens had been registered (except the holotype and paratypes) we tried to relocate the referred material as accurately as possible. One of us (L.G.M.) found twenty-five relatively complete crania (including holotype and paratypes) from the King Island collection in the National Museum, of which four were recognizably smaller than the rest. As no other complete (or relatively complete) crania were present in the collection and no record of loss or loan of any of the King Island dasyurid material appears in the museum directory (Mr T. A. Darragh, pers. comm.) we can assume with relative certainty that these crania represent the specimens studied by Spencer and Kershaw. The large crania referable to *D. bowlingi* were subsequently registered as P28832, 28836-28841, 28894-28897, 29636-29642 while the holotype (P15101, figured Spencer and Kershaw Pl. 8, fig. 1, p. 32 fig. A) (Pl. 11, fig. 1) and paratypes (P15102, figured Spencer and Kershaw Pl. 8, fig. 2; and P25940) (Pl. 11, figs. 2-3) were already numbered. P25940 has recently been selected as a paratype by Dr W. D. L. Ride and Mr T. A. Darragh because it was one of two specimens (the other being the holotype) which had a complete auditory bulla as discussed by Spencer and Kershaw (Pl. 11, fig. 3). Specimens P29641-29642 are represented only by the palate region; the cranial portion is missing. The four smaller skulls are assumed to be those assigned to *D. maculatus* by Spencer and Kershaw and are registered as P28833-28835 and P29635. In addition, cranial



J. A. M. 1816

G. S. 1816

NOUVELLE-HOLLANDE : NOUVELLE GALLES DU SUD.

DASYURUS À LONGUE QUEUE. (*DASYURUS MACROTIS* GÜNT.)

De l'ouvrage de L. J. G. S.

FIG. 1—Plate XXXIII from Lesueur and Petit's Atlas accompanying Péron and Freycinet (1807-1816) *Voyage de découvertes aux Terres Australes*. By courtesy of the R. G. Menzies Library, Australian National University.

fragments representing a minimum of three other individuals were present in the collection. These specimens were also without registration numbers and whether they were present when Spencer and Kershaw described the material or were added at a later date is unknown.

Spencer and Kershaw assigned 37 of the mandibles in their King Island collection to *D. bowlingi* and 29 to *D. maculatus*. (Although this totals 66, they give 60 as the sum of the mandibles, including the single specimen from Deal I.). In the NMV collection, however, a total of 90 mandibles are present, and the source of the additional 24 (or 30) is unknown. As with the crania, all were unregistered, except the paratypes, P15111 and P15112 (Spencer and Kershaw, *Ibid.* Pl. 8, figs. 4 and 5 respectively) (Pl. 12, figs. 1-2). The specimen noted by Spencer and Kershaw as coming from Deal Island could not be located, and it has probably been inadvertently mixed in with the King Island material. For the purposes of this study, seventeen representative mandibles were selected and given numbers P28898-28912.

Victorian specimens referred to *D. maculatus* include C1010, C2165, C2981, C6144, C6145, C6180, C7921, C8170, C9561, P7425, P7426, P28914-28919 (Pl. 11, fig. 4; Pl. 12, fig. 3). This sample includes a mixture of both male and female specimens although most are unsexed. The last eight specimens are from Holocene cave deposits. Specimen P7425 and 7426 represent the syntypes of *D. affinis* (= *D. maculatus*; see Mahoney 1964), and P28914-28919 were collected from a cave on the Point Addis Oil Lease in Western Victoria by Dr G. B. Pritchard (Pl. 11, fig. 4; Pl. 12, fig. 3). The Tasmanian sample consists of specimens C6115-6117, C6126, C6129, C6134, C6135, C6137, C6138; all of which are male.

A fossil cranial fragment in the collections of the Australian Museum (AM F54701) from western New South Wales was available for study. This specimen consists of most of the rostrum, the left cheek tooth series and the anterior part of the right maxilla, and associated left and right mandibles (Pl. 12, figs. 4-5). It was collected by Mr H. Allen, Department of Prehistory, A.N.U., from an Aboriginal hearth eroding out of consolidated dune deposits at the northern end of the dry Lake Mulurulu, on Willandra Creek, N.S.W. The dune deposits are more than 15,000 and probably about 24,000 years old (J. M. Bowler pers. comm.).

The following measurements were made on the crania and mandibles:— maximum length (L) and width (MW) of all premolars and molars, length of molar tooth row (M^{1-3} for upper teeth, M_{1-4} for lower), basal length and zygomatic breadth of skull and the depth and breadth of

the horizontal body of the mandible taken on labial side below M_3 .

The basal length of skull was measured from anterior edge of canine to posterior edge of occipital condyles and is not to be confused with the more conventional measurement of posterior edge occipital condyles to anterior edge I^1 . The former measurement was used because most of the King Island specimens lacked the premaxillary region.

All measurements are in millimeters.

AUDITORY BULLAE

Spencer and Kershaw (*Ibid.*, p. 32) used differences in the morphology of the auditory bullae to separate *D. bowlingi* and *D. maculatus*. They noted that in *D. viverrinus* the bullae are 'very largely inflated, the breadth of the bullae being at least three-quarter the length' while 'in *D. maculatus* the expansion of the bullae is not so great, the breadth being slightly more than half the length'. The bullae of *D. bowlingi* they recorded as 'more elongated and much less swollen'. Illustrations of these three types were given in Figures C, B and A respectively. Two specimens of *D. bowlingi* were recorded as having the auditory bullae (mastoid bullae of Spencer and Kershaw) sufficiently preserved to show the structure. As only P15101 (holotype) and P25940 (paratype) of the King Island specimens have this feature well preserved, these presumably are the specimens referred to. These were compared with all specimens of *D. maculatus* studied, and the bullae were found to vary greatly both in size and morphology. No differences, for example, could be observed between P25940, *D. bowlingi* and C7921, *D. maculatus* from Victoria.

The best example of bullae variation is seen in a modern specimen of *D. maculatus* (C6140) collected from Daintree River, Queensland (Pl. 12, fig. 6). The left bulla is large and inflated, and agrees perfectly with Figure B (*D. maculatus*) of Spencer and Kershaw; while the right bulla is narrow and less swollen than the left and agrees closely with their Figure A or *D. bowlingi* (holotype P15101). With such marked variation within a single individual, differences between individuals are to be expected.

CRANIAL AND DENTAL COMPARISONS

The cranial and dental measurements of the specimens from King Island, including three of the smaller crania (P28833-28835), the modern and subfossil sample of *Dasyurus maculatus* from Victoria, and the modern sample of *D. maculatus*

TABLE 1

Population parameters for some tooth an cranial dimensions of *Dasyurus maculatus* (subfossil and living) from Victoria;
D. "bowlingi" (subfossil), King Island; and *D. maculatus* (living), Tasmania

| Tooth dimension | <i>D. maculatus</i> , Victoria | | | | | <i>D. "bowlingi"</i> , King Island | | | | | <i>D. maculatus</i> , Tasmania | | | | |
|---|--------------------------------|------------|-------|--------|-------|------------------------------------|------------|--------|-------|-------|--------------------------------|------------|-------|-------|------|
| | N | O.R. | N | s | V | N | O.R. | M | s | V | N | O.R. | M | s | V |
| Upper cheek teeth | | | | | | | | | | | | | | | |
| P ₁ length | 13 | 3.0-3.8 | 3.40 | .245 | 7.21 | 17 | 2.9-3.8 | 3.36 | .296 | 8.80 | 8 | 3.0-3.5 | 3.28 | .158 | 4.82 |
| max. width | 13 | 1.5-2.0 | 1.75 | .166 | 9.49 | 17 | 1.6-2.3 | 1.98 | .188 | 9.49 | 8 | 1.7-2.1 | 1.88 | .149 | 7.93 |
| P ₂ length | 13 | 3.6-4.6 | 4.18 | .300 | 7.17 | 17 | 3.9-4.7 | 4.44 | .240 | 5.41 | 9 | 3.7-4.5 | 4.04 | .240 | 5.94 |
| max. width | 13 | 2.1-2.9 | 2.50 | .265 | 13.66 | 17 | 2.5-3.1 | 2.79 | .200 | 7.17 | 9 | 2.5-2.8 | 2.69 | .127 | 4.72 |
| M ₁ length | 13 | 5.4-6.8 | 6.02 | .462 | 8.01 | 17 | 5.9-6.5 | 6.15 | .203 | 3.30 | 9 | 5.6-6.1 | 5.90 | .187 | 3.17 |
| max. width | 13 | 3.8-5.0 | 4.22 | .389 | 9.22 | 17 | 4.5-5.1 | 4.76 | .158 | 3.32 | 9 | 4.1-4.5 | 4.33 | .150 | 3.46 |
| M ₂ length | 13 | 6.0-7.1 | 6.54 | .310 | 4.74 | 17 | 6.3-6.8 | 6.59 | .168 | 3.32 | 9 | 6.2-6.7 | 6.40 | .173 | 2.70 |
| max. width | 13 | 4.7-6.1 | 5.32 | .479 | 9.00 | 17 | 5.4-6.1 | 5.78 | .210 | 3.63 | 9 | 5.3-5.7 | 5.44 | .133 | 2.45 |
| M ₃ length | 13 | 6.2-7.3 | 6.82 | .352 | 5.16 | 17 | 6.7-7.4 | 7.02 | .195 | 2.78 | 9 | 6.6-7.0 | 6.79 | .154 | 2.27 |
| max. width | 13 | 5.7-7.1 | 6.45 | .416 | 6.45 | 17 | 6.2-6.8 | 6.58 | .205 | 3.12 | 9 | 5.8-6.5 | 6.27 | .212 | 3.38 |
| M ₄ length | 13 | 6.3-7.5 | 6.87 | .419 | 6.10 | 17 | 6.7-8.0 | 7.43 | .346 | 4.66 | 9 | 6.4-7.2 | 6.88 | .295 | 4.29 |
| max. width | 13 | 2.1-2.8 | 2.40 | .252 | 10.50 | 17 | 2.2-3.0 | 2.55 | .203 | 7.66 | 9 | 2.1-2.6 | 2.33 | .173 | 7.43 |
| M ₁ -M ₃ length | 13 | 17.7-20.8 | 19.23 | 1.049 | 5.45 | 17 | 18.8-21.0 | 20.04 | .560 | 2.79 | 9 | 18.0-20.2 | 19.04 | .637 | 3.35 |
| Lower cheek teeth | | | | | | | | | | | | | | | |
| P ₁ length | 11 | 3.6-4.2 | 3.90 | .155 | 3.97 | 14 | 3.0-4.2 | 3.89 | .308 | 7.92 | 9 | 3.8-4.1 | 3.93 | .112 | 2.85 |
| max. width | 11 | 1.7-2.0 | 1.86 | .129 | 6.94 | 14 | 1.7-2.3 | 2.06 | .160 | 7.77 | 9 | 1.8-2.0 | 1.96 | .0726 | 3.70 |
| P ₂ length | 13 | 3.9-4.7 | 4.28 | .203 | 4.74 | 17 | 3.9-4.7 | 4.34 | .218 | 5.02 | 9 | 4.0-4.3 | 4.16 | .101 | 2.43 |
| max. width | 13 | 1.9-2.6 | 2.25 | .211 | 9.38 | 17 | 2.1-2.6 | 2.40 | .137 | 5.71 | 9 | 2.2-2.4 | 2.29 | .0782 | 3.42 |
| M ₁ length | 15 | 4.5-5.5 | 4.92 | .305 | 6.20 | 17 | 4.0-5.6 | 5.22 | .230 | 4.41 | 9 | 4.6-5.3 | 4.83 | .224 | 4.64 |
| max. width | 15 | 2.7-3.3 | 3.01 | .179 | 5.95 | 17 | 3.1-3.5 | 3.29 | .139 | 4.22 | 9 | 3.0-3.2 | 3.12 | .0833 | 2.67 |
| M ₂ length | 15 | 5.3-6.5 | 5.87 | .411 | 7.00 | 17 | 5.6-6.6 | 6.16 | .272 | 4.42 | 9 | 5.6-6.0 | 5.82 | .120 | 2.06 |
| max. width | 15 | 3.2-4.0 | 3.59 | .245 | 6.82 | 17 | 3.6-4.3 | 3.88 | .194 | 5.00 | 9 | 3.4-4.0 | 3.63 | .173 | 4.77 |
| M ₃ length | 14 | 5.9-7.0 | 6.33 | .407 | 6.43 | 17 | 6.3-6.9 | 6.61 | .152 | 2.30 | 9 | 6.1-6.7 | 6.36 | .207 | 3.26 |
| max. width | 14 | 3.3-4.4 | 3.81 | .296 | 7.77 | 17 | 3.9-4.4 | 4.12 | .170 | 4.13 | 9 | 3.7-4.0 | 3.84 | .129 | 3.23 |
| M ₄ length | 15 | 6.0-7.0 | 6.51 | .358 | 5.50 | 17 | 6.5-7.2 | 6.81 | .196 | 2.88 | 9 | 6.3-6.8 | 6.53 | .180 | 2.76 |
| max. width | 15 | 3.3-4.0 | 3.70 | .217 | 5.86 | 15 | 3.7-4.3 | 3.98 | .190 | 4.77 | 9 | 3.6-3.8 | 3.72 | .0972 | 2.61 |
| M ₁ -M ₄ length | 15 | 18.8-25.4 | 23.39 | 1.752 | 7.49 | 17 | 23.5-26.0 | 24.89 | .845 | 3.39 | 9 | 23.0-25.0 | 23.81 | .670 | 2.81 |
| Breadth of mandible below M ₃ | 15 | 4.2-6.7 | 5.17 | .628 | 12.15 | 17 | 4.7-7.2 | 5.93 | .870 | 14.67 | 9 | 4.8-5.5 | 5.20 | .296 | 5.69 |
| Depth of mandible labial side M ₃ | 15 | 10.5-16.1 | 12.56 | 1.729 | 13.77 | 17 | 11.7-17.0 | 14.54 | 1.970 | 13.55 | 9 | 12.9-16.0 | 14.29 | 1.090 | 7.63 |
| Breadth of Zygomatic Arch | 10 | 48.5-71.0 | 61.82 | 8.032 | 12.99 | 17 | 54.0-73.0 | 66.69 | 6.262 | 9.39 | 9 | 59.4-68.0 | 64.41 | 2.89 | 4.49 |
| Basal length of skull ant. edge of canine to post. edge of occipital condyles | 12 | 75.0-109.0 | 95.15 | 11.420 | 12.00 | 17 | 84.0-112.7 | 102.15 | 9.468 | 9.27 | 9 | 90.0-106.0 | 98.39 | 5.29 | 5.38 |

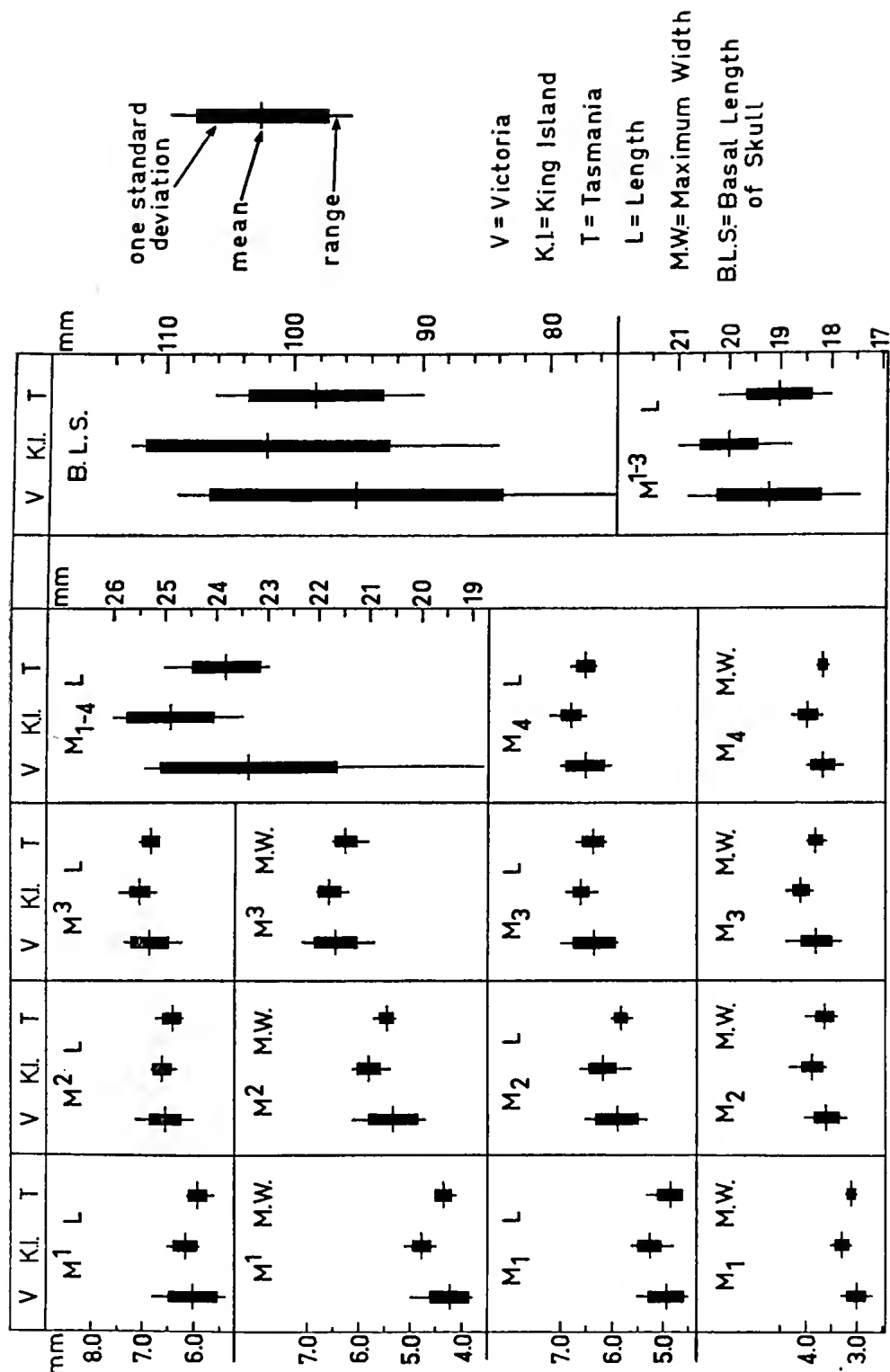


FIG. 2.—Bar diagram comparing dental and cranial dimensions of a modern male sample of *Dasyurus maculatus* from Tasmania, a modern and subfossil sample of *D. maculatus* from Victoria, and a subfossil sample of *D. bowlingi* from King Island, Bass Strait.

from Tasmania are given in Table 1. Means, standard deviations and coefficients of variation were determined following the procedures set out by Simpson et al. (1960). Several measurements are shown graphically in Fig. 2.

The means for each character are very similar in all three populations and there is considerable overlap in the ranges, but the specimens from King Island tend to be slightly larger than those from the other localities. The coefficients of variation of tooth dimensions of the mixed Victorian sample range from 3.97–10.60, with most lying between 5 and 8. The range is equally wide in the King Island sample, from 2.30 to 9.49, with the majority in this case lying between 2 and 6. For the cranial and mandibular dimensions, the coefficients of variation of both these populations are much greater, ranging from 12.00 to 13.77 in the Victorian sample and from 9.27 to 14.67 in the King Island sample. In contrast, the coefficients of variation for the Tasmanian sample range from 2.61–7.93 for the tooth dimensions, 2.4 occurring most frequently, and from 4.49 to 7.63 for the cranial and mandibular dimensions. This variation is about half that of the Victorian sample. As the Tasmanian sample consists entirely of males, the greater variability in the other two samples may be the result of a marked sexual dimorphism.

In the Victorian sample a single specimen was labeled as female (C8170) and three (C6180, C2981, C2165) as male. The lengths of M¹⁻³, zygomatic breadth, and basal length of skull of the female are 17.7, 48.5, and 75.0 respectively; for the three males the equivalent measurements are 19.4, 18.6, 19.2; no measurement, 62.5, no measurement; 99.0, 95.0, 95.5. Although this sample is small, a marked size difference is evident between the two sexes, with the female being the smaller.

Sexual dimorphism is common among dasyurids. Green (1967) found that males of *D. viverrinus* and *Sarcophilus harrisii* from Tasmania were significantly larger in cranial dimensions and overall body size than females. In both species females had a body weight about one-third less than males. A significant sexual dimorphism was also found in *Thylacinus cynocephalus* in which females were smaller than males (Ride 1964). Here the disparity in size was so marked that there was no overlap of measurements in seven of the eight characters considered. Among the smaller dasyurids sexual dimorphism in both body size and cranial dimensions has been found in *Antechinus flavipes*, *A. godmani*, *A. minimus*, *A. stuartii*, and *A. swainsonii*, males being larger than females in all cases (Wakefield and Warneke 1963, 1967).

The effect of the three smaller crania (P28833–28835) upon the ranges of the various measurements of the King Island sample is most clearly seen in the basal length and zygomatic breadth of the skull. The ranges of these two measurements for the three smaller specimens are 84.0–87.0 and 54.0–57.0 respectively, while the smallest specimens in the remainder of the King Island sample measure 96.0 (P28836) and 63.5 (P28895) respectively. When the three smaller skulls are omitted from the sample, the range of coefficients of variation of the King Island sample of large skulls (*D. bowlingi*) is almost identical with the male sample from Tasmania.

The sexual dimorphism shown in modern Victorian specimens of *D. maculatus* and the close similarity of range and coefficients of variation of the *D. bowlingi* sample to the male Tasmanian sample of *D. maculatus* suggests that *D. bowlingi* was erected on a subfossil sample of males of *D. maculatus*, and the smaller skulls in the King Island collection are those of females. Spence and Kershaw (1910, p. 32) considered this possibility but at that time no adequate studies on sexual dimorphism had been made on the dasyurids or related species. The distribution of the King Island sample into 'two sets' were thus interpreted as representing specific differences.

On the foregoing evidence, *Dasyurus bowlingi* Spence and Kershaw 1910, is recorded here as a junior subjective synonym of *Dasyurus maculatus*.

A certain degree of bias is present in Spence and Kershaw's presentation and deserves comment. Firstly, their table (*Ibid.* p. 30) comparing basal length of skull was constructed using integers of 10 mm for *D. viverrinus* and *D. maculatus* and of 5 mm for their King Island specimens, giving an impression of a greater range of size in the latter than was real. Secondly, the holotype (P15101) is the longest specimen in basal length (112.7 mm) and second only to P28838 in zygomatic breadth (72.2 and 73.0 respectively). Good preservation of the right auditory bulla in P15101 may be argued in favour of the choice of this specimen as the holotype.

In general, the specimens from King Island tend to be larger than those from Victoria or Tasmania. But of the 15 cranial upper teeth measurements of the mixed Victorian sample, the three subfossil specimens from the Point Addis Oil Reserve, Victoria, mark the upper limits in 13 cases. If these specimens (P28914–16) are compared with the holotype (P15101) and paratypes (P15102, 25940) of *D. bowlingi* (Table 2) a striking similarity is seen. In fact, the subfossil Victorian specimens are larger than the King Island speci-

TABLE 2
Selected cranial and cheek tooth dimensions of *D. "bowlingi"* from King Island compared with subfossil specimens of *D. maculatus* from Victoria and a late Pleistocene specimen from New South Wales

| Specimen | P 1 | | P 2 | | M 1 | | M 2 | | M 3 | | M 4 | | M ¹⁻³ M ₁₋₄ | Zygomatic breadth | Basal length of skull |
|--------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--------------------------------------|----------------------|-----------------------------|
| | L | MW | L | MW | L | MW | L | MW | L | MW | L | MW | | | |
| Upper cheek teeth | | | | | | | | | | | | | | | |
| <i>D. "bowlingi"</i> | | | | | | | | | | | | | | | |
| P15101 (Holotype) ^a | 3.4 | 2.0 | 4.7 | 2.7 | 6.2 | 4.7 | 6.8 | 5.7 | 7.1 | 6.6 | 8.0 | 2.4 | 20.5 | 72.7 | 112.7 |
| P15102 (Paratype) ^a | 3.0 | 2.0 | 4.2 | 2.8 | 6.2 | 4.8 | 6.7 | 6.0 | 7.0 | 6.7 | 7.7 | 2.6 | 19.9 | 71.3 | 106.8 |
| P25940 (Paratype) ^a | 3.4 | 2.3 | 4.5 | 3.0 | 6.5 | 4.8 | 6.8 | 6.0 | 7.2 | 6.8 | 7.6 | 2.7 | 20.1 | 72.2 | 106.0 |
| <i>D. maculatus</i> | | | | | | | | | | | | | | | |
| P28914 ^b | 3.6 | 2.0 | 4.6 | 2.9 | 6.7 | 5.0 | 6.9 | 6.1 | 7.1 | 7.1 | 7.0 | 2.7 | 20.3 | 71.0 | 109.0 |
| P28915 ^b | 3.4 | 2.0 | 4.6 | 2.9 | 6.8 | 4.8 | 6.8 | 6.0 | 7.3 | 6.7 | 7.5 | 2.6 | 20.8 | 71.0 | 104.0 |
| P28916 ^b | 3.8 | 2.0 | 4.6 | 2.8 | 6.6 | 4.6 | 6.7 | 5.8 | 7.3 | 6.9 | 7.2 | 2.7 | 20.3 | 65.0 | 109.0 |
| AM F54701 ^c | 3.7 | 2.0 | 4.6 | 3.0 | - | - | 7.0 | 6.1 | 7.1 | 7.2 | 8.0 | 2.6 | 20.9 ^d | - | - |
| Lower cheek teeth | | | | | | | | | | | | | | | |
| <i>D. "bowlingi"</i> | | | | | | | | | | | | | | | |
| P15111 ^a | - | - | 4.1 | 2.6 | 5.2 | 3.1 | 6.6 | 3.9 | 6.7 | 4.2 | 7.0 | 4.2 | 24.8 | - | - |
| P15112 ^a | - | - | 4.2 | 2.4 | 5.6 | 3.4 | 6.5 | 4.0 | 6.7 | 4.1 | 7.0 | 4.0 | 25.7 | - | - |
| <i>D. maculatus</i> | | | | | | | | | | | | | | | |
| P28917 ^b | 3.9 | 2.0 | 4.2 | 2.4 | 5.2 | 3.2 | 6.3 | 3.8 | 6.8 | 3.8 | 7.0 | 3.8 | 25.1 | - | - |
| P28918 ^b | - | - | 4.7 | 2.6 | 5.4 | 3.3 | 6.5 | 4.0 | 6.9 | 4.4 | 7.0 | 4.0 | 25.2 | - | - |
| P28919 ^b | 4.0 | 2.0 | 4.4 | 2.6 | 5.5 | 3.3 | 6.4 | 3.8 | 7.0 | 4.1 | 6.8 | 3.9 | 25.4 | - | - |
| AM F54701 (left) ^c | - | - | - | - | - | - | 6.6 | 4.3 | 7.0 | 4.4 | 7.2 | 4.4 | - | - | - |
| AM F54701 (right) ^c | - | - | - | - | - | - | 6.6 | 4.1 | 7.0 | 4.4 | 7.3 | 4.4 | - | - | - |

abbreviations: L, length; MW, maximum width.

^a King Island, Bass Strait

^b Holocene cave, Point Addis Oil Reserve, Victoria

^c Lake Mulurulu, New South Wales

^d approximate

mens in 10 of the 15 characters considered. The presence of these large subfossil specimens in the Victorian sample may contribute as much to the exceptionally high variability of the latter as does the sexual dimorphism of the population. However the modern and subfossil specimens from Victoria are not separable on other morphological grounds and their treatment as a single sample is believed justified.

Similarly the Pleistocene specimen from Lake Mulurulu, N.S.W., is larger than the holotype and paratypes of *D. bowlingi* in five upper tooth measurements and equal or smaller in six (Table 2).

With respect to lower teeth measurements, the two paratypes of *D. bowlingi* (P15111, 15112) are also comparable directly with the three subfossil mandibles of *D. maculatus* from Victoria (P28917-28919), and the late Pleistocene mandibles from Lake Mulurulu, New South Wales (Table 2). The subfossil Victorian specimens are equal to or larger than *D. bowlingi* in six of the eleven characters compared; while the Mulurulu specimen is equal in one and larger in five of the six characters compared.

The taxonomic status of two other large dasyurids deserves comment. *Dasyurus affinis* McCoy, 1865 was 'erected by a note on a Geological Survey of Victoria Sheet & N.W.' in a list of mammals from the Bone Cave S. by E. of Gisborne, Victoria (Mahoney 1964). The syntypes, two left mandibles (P7425, 7426) agree in size and morphology with *D. maculatus* and the species is recognised as a junior synonym of the latter (*Ibid.* p. 526). These mandible are considerably smaller than the specimens just discussed and may represent females, or the deposit may be younger in age. The age of Gisborne Cave is considered as Holocene (Gill, in appendix of Mahoney 1964).

Dasyurus gracilis was long thought to be a small Queensland form closely related to *D. maculatus*, but specifically distinct. The type specimen is a young juvenile in which M⁴ is not yet erupted (AM M155). Tate (1952) considered it as conspecific with *D. maculatus* on the basis of a large number of specimens representing a complete growth series. Having examined specimens of *D. maculatus* from Queensland (C6140, 6141) which are regarded as representing the '*gracilis*' race, we concur with Tate's conclusion.

Dasyurus dunmali, from the late Pliocene Chinchilla Sand of southern Queensland, is similar in size and morphology to *D. viverrinus* (Bartholomai 1971), and *Dasyurus mordax* (Owen 1877, Pl. V, fig. 10) also seems to be closer to the smaller species of *Dasyurus* than to *D. maculatus*.

DISCUSSION

It seems probable that the late Pleistocene-early Recent mainland population and the isolated, but modern population on King Island were both slightly larger than the modern mainland and Tasmanian ones. It may be that *Dasyurus maculatus* provides another example of post-Pleistocene dwarfing as has been suggested for other species. For example, Lydekker (1887) suggested that *Sarcophilus laniarius* of the late Pleistocene may have been directly ancestral to the smaller modern species *S. harrisii*. He also proposed a similar phyletic line for *Macropus titan* - *M. giganteus* and *Osphranter altus* (= *O. cooperi*) - *O. robustus*. *Macropus siva* may similarly represent a larger Pleistocene form of *M. agilis* and *Wallabia vishnu* of *W. bicolor* (A. Bartholomai, pers. comm.).

However such differences in size may also be attributable to geographic factors. For example, Ride (1964) has shown that while fossil *Thylacinus cynocephalus* from eastern Australia are slightly larger than the modern Tasmanian ones, the fossil population from western Australia was smaller than both the eastern fossil or the modern population. The larger specimen of *D. maculatus* from Lake Mulurulu, N.S.W. is particularly relevant in this respect, as it was found in a context atypical of modern populations of the species. It was collected in association with a suite of species, including *Bettongia penicillata*, *B. lesueur*, *Lagorchestes* sp. and *Onychogalea* sp., suggestive of a semi-arid environment. Modern *Dasyurus maculatus* has never been recorded from such a habitat, and prefers much wetter conditions. However Lake Mulurulu contained water at the time and a riparian woodland may have grown on its shores, as Tedford (1967) has suggested for nearby Lake Menindee.

The subfossil specimens of *D. maculatus* from King Island are certainly not of Pleistocene age. Extinct marsupials including *Zygomaturus trilobus*, *Protemnodon anak* and *Diprotodon optatum*, have been recorded from swamp deposits in the north of King Island, and others, including *Sthenurus occidentalis*, have been found embedded in older, consolidated dunes at Surprise Bay (Hope 1973). However the remains of *D. maculatus* are all from younger unconsolidated dunes and are associated with modern species. These include some, such as *Macropus rufogriseus* and *Thylagale billardieri*, which are still present on King Island, and others, such as *Vombatus ursinus* and the King Island emu, *Dromaius ater*, which although now extinct there, were recorded alive on the island in 1802 (Péron and Freycinet 1816). The younger dunes of King Island are probably of Holocene age.

(Jennings 1959), and the subfossils found in them are of comparatively recent age, as the species concerned are those still present on the islands or ones which have become extinct within historic times.

Variations in body size are very common in island populations of mammals. Foster (1964) has summarised the trends in different groups and has found that rodents tend to increase in body size when isolated, while other mammals such as carnivores and artiodactyls tend to diminish in size. There are several recorded examples of island populations of marsupials which are smaller in size, such as the form of *Isodon obesulus* found on two islands of the Nuyts Archipelago, S.A. (Wood Jones 1923-1925) but none, that we are aware of, where an increase in body size has occurred. Other marsupial species on the islands of Bass Strait such as *Potorous apicalis* and *Thylgale billardieri* tend to be smaller than their mainland counterparts (Hope 1973). At first sight, the large size of the tiger cat on King Island seems an unexpected reverse of this trend. However increases in body size in insular rodent species have been attributed to a lack of competitors (e.g. Corbet 1964) which has enabled the insular species to utilise a wider range of habitats.

On King Island, *D. maculatus* had no competition, as the larger predators such as *Thylacinus cynocephalus*, *Sarcophilus lanarius* and the dingo were absent, and was probably able to exploit larger sized prey (and carrion?) species. Lesueur and Petit's illustration of two tiger cats eating a seal carcass is of interest in this context. Larger size would presumably be a favourable development for the tiger cat in this situation.

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EXPLANATION OF PLATES

PLATE 11

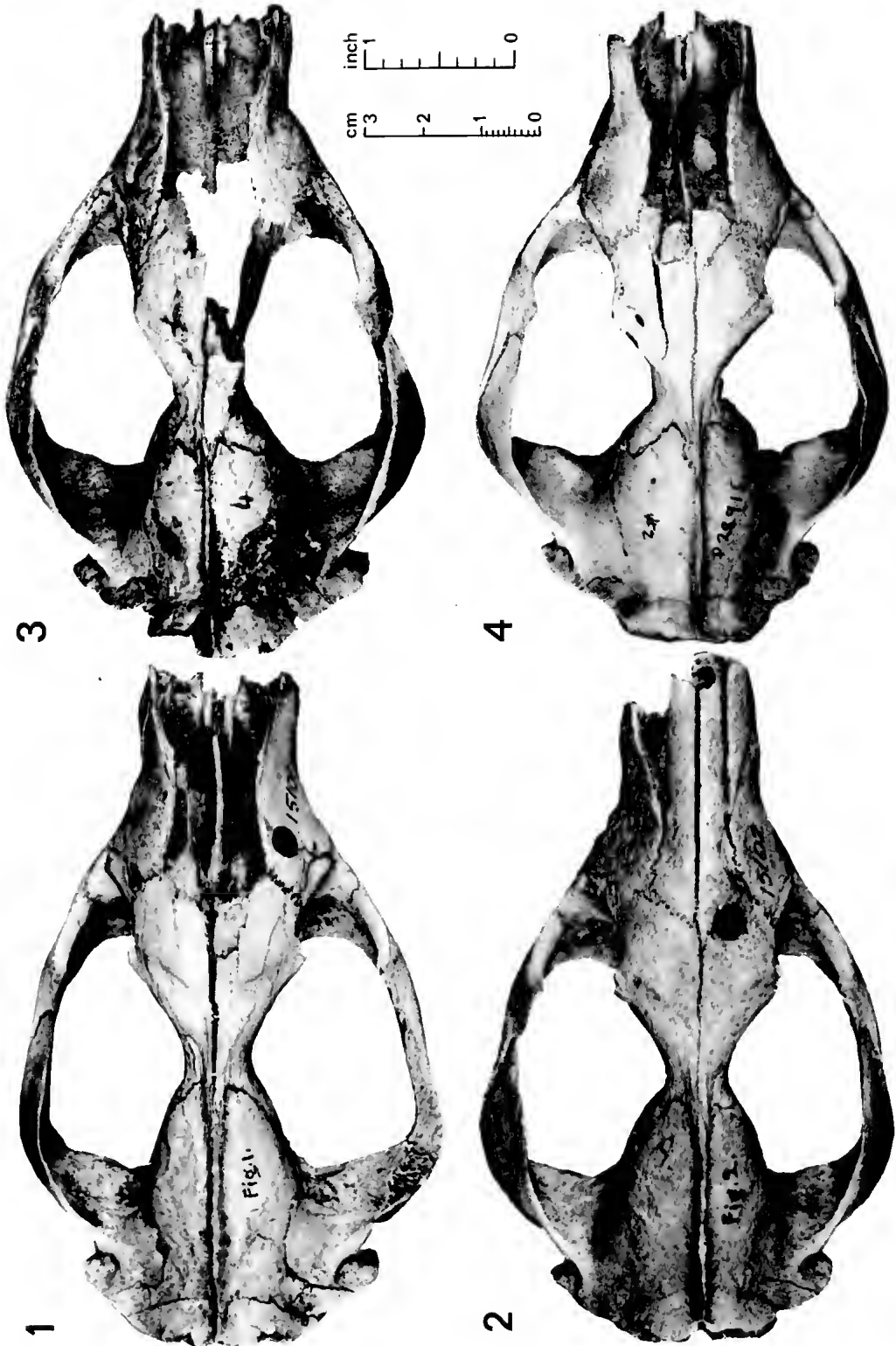
FIGS. 1-3—*Dasyurus bowlingi* Spencer and Kershaw. 1. P15101 (holotype). 2. P15102 (paratype). 3. P25940 (paratype). All dorsal views. King Island, Bass Strait.

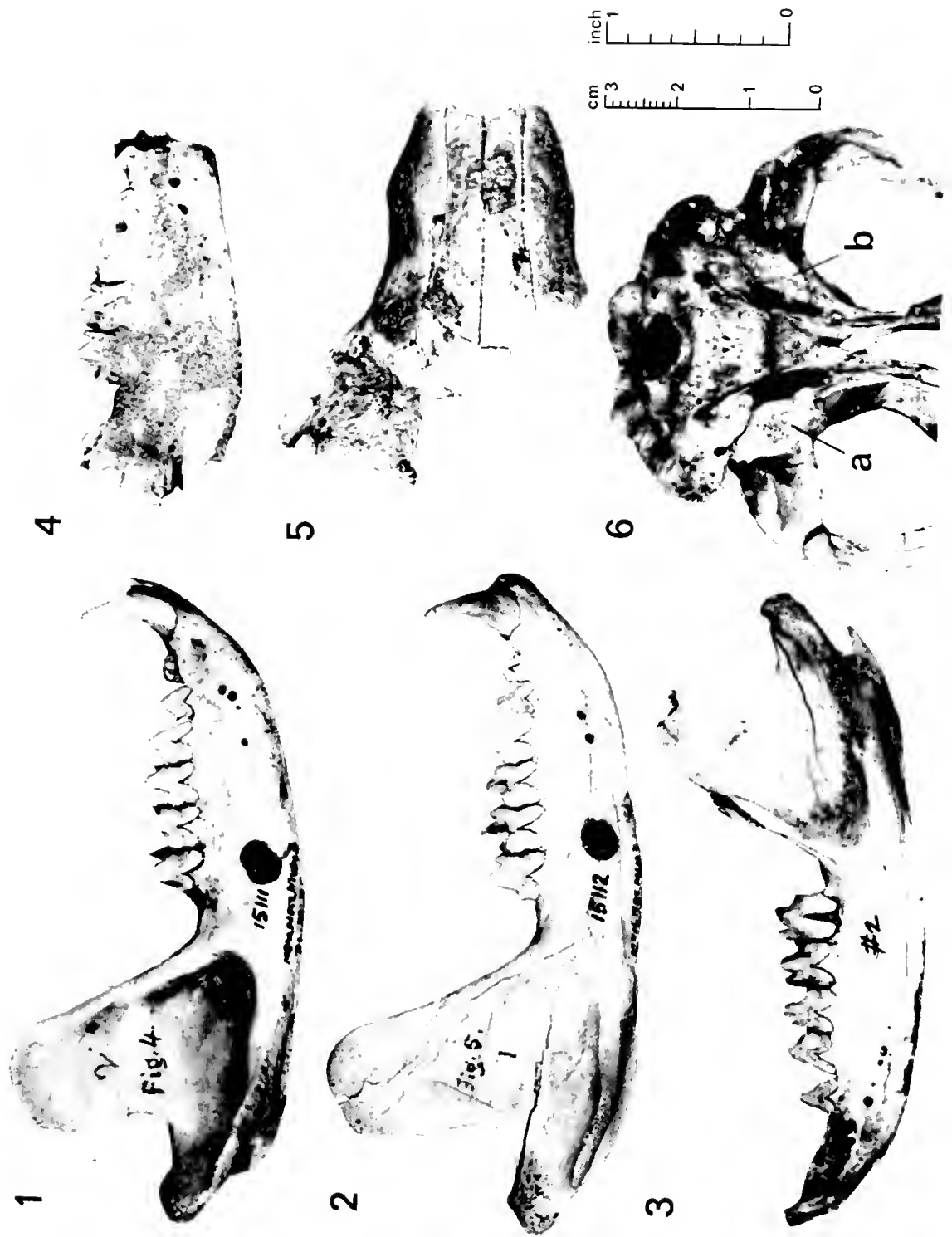
FIG. 4—*Dasyurus maculatus* (Kerr). P28915, dorsal view. From cave on Point Addis Oil Lease, Victoria.

PLATE 12

FIGS. 1-2—*Dasyurus bowlingi* Spencer and Kershaw. 1. P15111 (paratype). 2. P15112 (paratype). Both labial views of right mandible. King Island, Bass Strait.

FIGS. 3-6—*Dasyurus maculatus* (Kerr). 3. P28918, from cave on Point Addis Oil Lease, Victoria. Labial view of left mandible. 4. AM F54701, labial view of right mandible. 5. AM F54701, dorsal view of rostrum; from Lake Mulurulu, southwestern New South Wales. 6. C6140, ventral view of cranium; from Daintree River, Queensland. Note the disproportionate size of the auditory bullae.





TERTIARY AND LATE CRETACEOUS SPORES AND POLLEN FROM THE GIPPSLAND BASIN, SOUTHEASTERN AUSTRALIA

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ABSTRACT: The Gippsland Basin in southeastern Australia lies partly onshore but mainly offshore and contains a relatively thick sequence of dominantly non-marine strata. In the western inland portion, the section is represented by extensive Oligocene and Miocene coals of the Latrobe Valley Coal Measures, whereas in the coastal and offshore portions it consists mainly of Late Cretaceous through Eocene clastics and coals of the Latrobe Group. The abundant, diverse, and stratigraphically significant spores and pollen from these sections are the main subject of this paper. In all, 147 species are considered; this includes the description of the following 10 new form genera: *Anisotricolporites*, *Bysmapollis*, *Concolpites*, *Drytopollenites*, *Gephyrapollenites*, *Helcioporites*, *Herkosporites*, *Paripollis*, *Quadrplanus*, *Schizocolpus*; and 65 new form species which account for a substantial increase in the number of spore-pollen species identified from the Australian Tertiary. In addition, revised descriptions are provided and lectotypes or neotypes are selected for several previously described species, mostly proteaceous pollen. Based primarily on the ranges of the spores and pollen as determined in the Gippsland Basin, ten biostratigraphic zones are recognized. The diagnostic features of the Late Cretaceous through early Eocene offshore zones (*Nothofagidites senectus* through *Proteacidites asperopolus* Zones) are summarized; the middle to late Eocene Lower *Nothofagidites asperus* Zone is redefined on the basis of new information from onshore sections, and three new zones—the Upper *Nothofagidites asperus*, the *Proteacidites tuberculatus* and the *Triporopollenites bellus* Zones—are introduced to cover the latest Eocene through Miocene part of the section in the onshore portion of the basin.

INTRODUCTION

Tertiary palynology in southeastern Australia began in the mid-1940's with the publication on fossil *Nothofagus* (Southern beech) pollen by Cookson (1946) and on Oleaceae (Olive family) pollen and megafossils, also by Cookson (1947). Between then and 1955, a series of short papers appeared in which different types of Australian fossil pollen and spores were described. For example, in 1950 Cookson described several species of fossil proteaceous pollen; fossil gymnosperm pollen were discussed by Cookson (1953) and by Cookson and Pike (1953, 1953, 1954) and numerous angiosperm pollen species were proposed by Cookson and Pike (1954). By and large, these publications as well as two later papers (Cookson 1957, 1959) emphasized the morphology of the forms and their similarity and possible affinity to the pollen and spores of Holocene plants.

Cookson's 1954 report on the spores and pollen from the V.M.D. Birregurra-1 bore in Victoria represented the first attempt in southeastern Australia to characterize, label, and use Tertiary spore pollen assemblages as a means for correlating surface and subsurface sections. She recognized three distinct spore-pollen assemblages in the Birregurra-1 bore which were designated in ascending order Microflora A (Cretaceous), Microflora B (Paleocene to early Eocene), and Microflora C (Eocene). About 25 spore-pollen species were reported from the two Tertiary assemblages and the occurrences of these species in similar assemblages from nearby Otway Basin surface sections were shown.

Subsequently, little was published on Australian Tertiary spore-pollen assemblages until the contribution by Harris (1965) on the sequence of spore-pollen assemblages in the Princetown area of Victoria between Dilwyn Cove and the mouth

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of the Gellibrand River. The oldest assemblage—the *Triorites edwardsii* (= *Gambierina edwardsii*) Assemblage—occurred in the Pebble Point Formation and the lower part of the Dilwyn Clay. This assemblage was dated as middle Paleocene and was considered in part equivalent to Cookson's Microflora B. The next youngest assemblage—the *Triorites edwardsii*—*Duplopollis orthoteichus* (= *Cupanieidites orthoteichus*) Concurrent Range assemblage occurred in the Rivernook member of the Dilwyn Clay and in the strata above the Rivernook member and below the *Turritella* Bed. This spore-pollen assemblage was interpreted as middle to late Paleocene and presumably came between Cookson's Microfloras B and C. Harris's youngest assemblage—the *Duplopollis orthoteichus* Assemblage—occurred in the section from the *Turritella* bed to the top of the fossiliferous section at Princetown, and includes the Princetown member. The assemblage was interpreted as late Paleocene and as being somewhat older than Cookson's Microflora C. Neither the top of the *Duplopollis orthoteichus* Assemblage nor the base of the *Triorites edwardsii* Assemblage were defined.

The status of Tertiary palynology at about the time the first offshore Gippsland Basin well (Barracouta-1) was drilled, which was also about the time that Harris's paper appeared was:

1. About 100 species of fossil spores and pollen were described from Paleocene through Pliocene samples.
2. The samples, for the most part, were from scattered, isolated localities with little stratigraphic control or continuity.
3. The ranges were undetermined for all but a very few species, and except for the publications on the Princetown area and the Birregurra-1 bore, the qualitative and quantitative composition of the spore-pollen assemblages were essentially unknown.
4. The sequential succession of assemblages and their spatial relationships had not been determined.

Since then, the characteristics of assemblages from western Victoria and eastern Southern Australia were elucidated by Harris (1971) and a considerable amount of new information on spore-pollen assemblages and their distribution in south-eastern Victoria became available from petroleum exploration wells in the offshore portion of the Gippsland Basin. More recently, Harris (1972) described and illustrated 16 new species from South Australia. At the present time, an estimated 250 to 300 species of fossil spores and pollen are known from Late Cretaceous through Miocene sections of the Gippsland Basin. Of these species,

approximately 140 are stratigraphically important.

In 1971, Stover and Evans (ANZAAS Brisbane Congress, May 1971; manuscript submitted for publication in the Dr I. C. Cookson Memorial Volume, Geol. Soc. Australia Special Publication No. 4) presented the spore-pollen zonation for the offshore portion of the Gippsland Basin and illustrated a few of the diagnostic forms from each of the Zones. A short time later Partridge completed a study of the spore-pollen assemblages from the onshore portion of the basin (Partridge, 1971, M.Sc. Thesis) in which he recognized and defined additional zones. A comparatively large number of undescribed spore and pollen species, of which the majority have stratigraphic significance, were discovered in assemblages from offshore and onshore sections, and because most of the new forms occur in both portions of the basin, it is appropriate that they be introduced in a single publication. The purposes of this paper, then, are to describe, illustrate, and discuss the spore-pollen species from Late Cretaceous through Miocene assemblages of the Gippsland Basin, to indicate their ranges, and formally to present the zonation for the onshore portion.

The Gippsland spore-pollen zonation resulted from the examination of approximately 800 conventional and sidewall cores from offshore wells and an additional 130 samples from onshore wells and coal localities. Locations of the offshore wells are shown in Stover and Evans (1973) and Fig. 1 shows the locations of the onshore wells and surface localities, and those offshore wells from which type specimens of species described herein were selected. More precise locality data are presented in the register of localities and specimens at the end of the paper.

This spore-pollen zonation is most applicable in dominantly non-marine and marginal marine sections. The Late Cretaceous through Eocene zones are found mainly in the offshore portion of the basin where they are developed and documented best in the Latrobe Group. This group contains quartzose sandstones, coals, mudstones, siltstones and shales, and attains an estimated maximum thickness of 15,000 ft in the basin deep (James & Evans, 1971). The Latrobe Group is overlain unconformably by marine Oligocene strata which, in turn, are overlain conformably by Miocene and possibly younger Tertiary and Quaternary rocks. The Oligocene and Miocene spore-pollen zones are developed and documented best in the onshore portion of the basin and are expressed most favorably in the Latrobe Valley Coal Measure (Gloe, 1967). This group, which occurs in the Latrobe Valley where it reaches a maximum thickness of

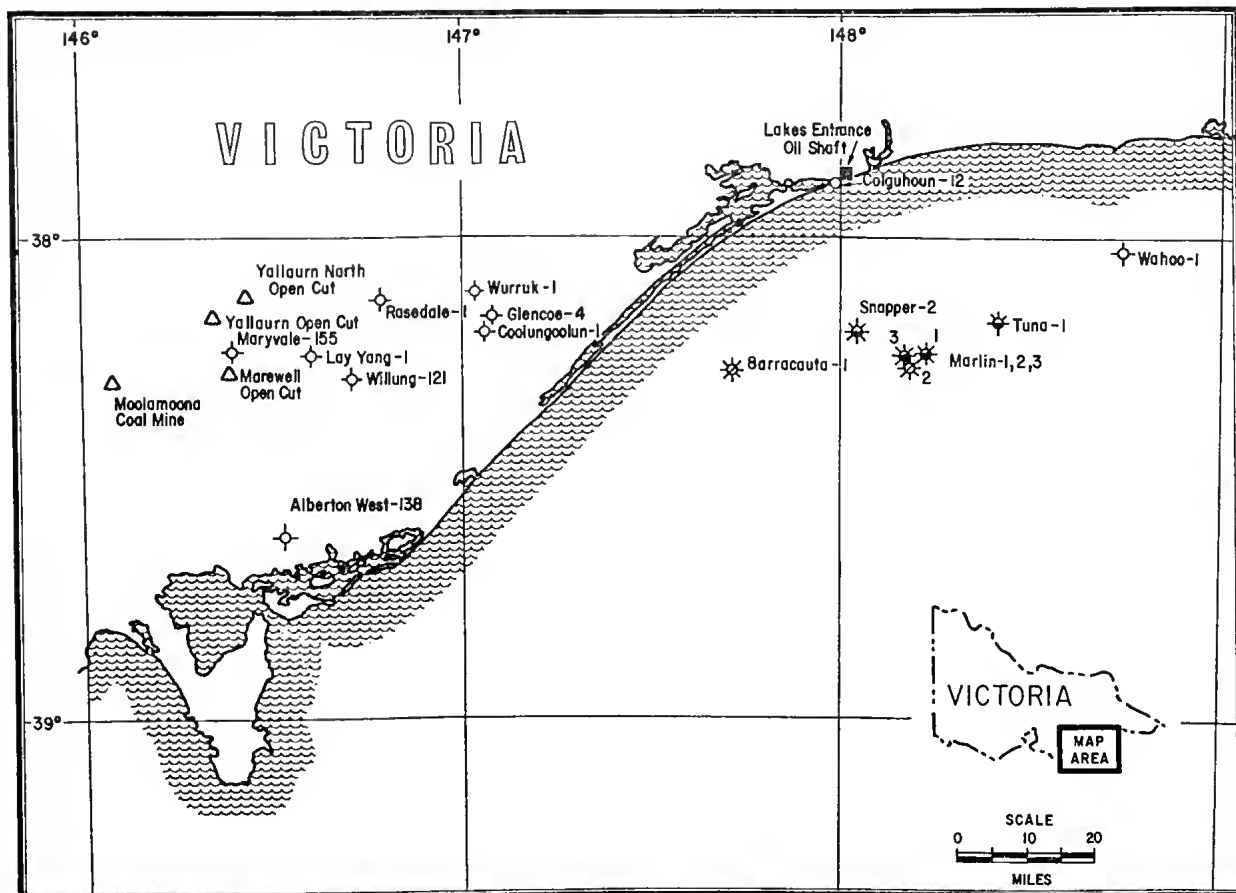


FIG. 1—Location Map.

more than 2000 ft, is dominated by thick brown coal seams in the upper part and by interbedded sandstones, clays, coals and volcanics in the lower part. Middle and late Eocene zones are developed better in the onshore sections in the lower part of the Latrobe Valley Coal Measures.

SPORE-POLLEN ZONES

The following biostratigraphic Zones are recognized in the Late Cretaceous and Tertiary sections of the Gippsland Basin:

Triporopollenites bellus Zone—late Miocene, possibly into Pliocene.

Proteacidites tuberculatus Zone—early Oligocene into early Miocene.

Upper *Nothofagidites asperus* Zone—late Eocene into early Oligocene.

Lower *Nothofagidites asperus* Zone—middle Eocene to late Eocene.

Proteacidites asperopolus Zone—early Eocene.

Malvacipollis diversus Zone—early Eocene.

Lygistepollenites balmei Zone—middle and late Paleocene.

Tricolpites longus Zone—early Paleocene, possibly into middle Paleocene.

Tricolporites lilliei Zone—Late Cretaceous (Maastrichtian equivalent).

Nothofagidites senectus Zone—Late Cretaceous (Senonian equivalent).

Because the criteria for the recognition of each Zone from the *Nothofagidites senectus* through the *Proteacidites asperopolus* Zones are given in Stover and Evans (1973), only the major features of these Zones are given below. A more complete discussion of the Lower *Nothofagidites asperus* Zone which takes into account information from onshore sections is presented, as well as discussions on the Zones proposed in this paper. The accompanying stratigraphic chart (Fig. 3) shows the ranges of the species described here and of selected previously described species. Modifications in the ranges of some forms were necessary and the in-

formation depicted on Fig. 3 supersedes that given in Stover and Evans (1973). Throughout author and date citations are given only for those species excluded in the descriptive paleontology section.

Nothofagidites senectus ZONE

DIAGNOSTIC FEATURES: Base is defined by the introduction of *Nothofagidites* pollen of the *brassi* group including the nominate species, *N. senectus*, in association with *Gambierina rudata*, *Proteacidites amolosexinus*, *Tricolpites gillii* and *T. sabulosus*. Top is marked by the first appearance of *Tricolporites lilliei* together with other species indicative of the *T. lilliei* Zone.

ASSOCIATED FORMS: Mainly long-ranging species such as *Laevigatosporites ovatus* Wilson & Webster 1946, *Cyatlidites minor* Couper 1953, *Lycopodiumsporites austroclavitudites* (Cookson) Potonié 1956, *Cicatricosisporites australiensis* (Cookson) Potonié 1956, *Gleicheniidites cercinidites* (Cookson) Dettmann 1963, *Microcachyridites antarcticus* Cookson 1947 and *Phyllocladidites mawsonii*.

OCCURRENCE: Offshore portion of the Gippsland Basin with reference sections given by Stover and Evans (1973).

AGE: Late Cretaceous (Senonian equivalent).

CORRELATIVES: Probably a correlative of the *Tricolpites pachyexinus* Zone and certainly of the lower part of the *Nothofagidites* Microflora interval in the Otway Basin (Dettmann & Playford, 1969).

Tricolporites lilliei ZONE

DIAGNOSTIC FEATURES: Base is defined by the nearly simultaneous initial occurrence of *Gephyrapollenites wahooensis*, *Latrobosporites amplius*, *L. ohaiensis*, *Lygistepollenites balmei*, *Nothofagidites endurus*, *Ornamentifera sentosa*, *Proteacidites palisadus*, *P. scaboratus* Couper 1960, *Tricolpites confessus*, *Triporopollenites sectilis* and the nominate species. *Tricolpites sabulosus* terminates within the Zone, whereas *Gambierina edwardsii*, *Lygistepollenites florinii*, *Phyllocladidites verrucosus*, *Quadruplanus brossus*, *Simplicipollis meridianus*, *Stereisporites regium* and *Tricolpites longus* appear within the Zone, mostly in the uppermost part. Top is marked by the introduction of species indicative of the *Tricolpites longus* Zone.

OTHER FEATURES: Increase in the relative abundance of *Nothofagidites* spp. and a greater diversity of angiosperm pollen than found in the *N. senectus* Zone.

OCCURRENCE: Offshore portion of the Gippsland

Basin with reference sections given by Stover and Evans (1973).

AGE: Late Cretaceous (Maastrichtian equivalent).

CORRELATIVES: Upper part of the *Nothofagidites* Microflora interval in the Otway Basin (Dettmann & Playford, 1969).

Tricolpites longus ZONE

DIAGNOSTIC FEATURES: Base is defined by the introduction of *Dilwynites granulatus*, *Latrobosporites crassus*, *Proteacidites angulatus*, *Stereisporites* (*Tripunctisporis*) spp. and *Tetracolporites verrucosus*. The ranges of *Nothofagidites senectus*, *Proteacidites palisadus* and *P. amolosexinus* terminate whereas those of *Australopollis obscurus*, *Ilexpollenites anguloclavatus* begin within the Zone. Species recorded last at or near the top of the Zone are *Latrobosporites amplius*, *Quadruplanus brossus*, *Tricolpites confessus*, *Tricolporites lilliei*, *Triporopollenites sectilis* and the nominate species.

OTHER FEATURES: Absence or very low number of *Nothofagidites* spp. and common occurrence of *Gambierina* spp.

OCCURRENCE: Offshore portion of the Gippsland Basin with reference sections given by Stover and Evans (1973).

AGE: Early to possibly middle Paleocene; the boundary between the *Tricolporites lilliei* and *Tricolpites longus* Zones approximates the Mesozoic—Tertiary boundary.

CORRELATIVES: None known in southeastern Australia.

Lygistepollenites balmei ZONE

DIAGNOSTIC FEATURES: Base is defined by the earliest and nearly coincident appearance of *Haloragacidites harrisii*, *Herkosporites elliottii*, *Nothofagidites brachyspinulosus*, *Peromonolites densus*, *P. vellosus*, *Phyllocladidites reticulosaccatus*, *Polycolpites langstonii*, *Rugulatisporites mallatus* and *Tricolpites phillipsii*. Top of the Zone is marked by the essentially simultaneous last occurrence of *Australopollis obscurus*, *Ceratospores equalis* Cookson & Dettmann 1958, *Gambierina rudata*, *Lygistepollenites ellipticus*, *Phyllocladidites reticulosaccatus*, *P. verrucosus*, *Polycolpites langstonii* and the nominate species.

OTHER FEATURES: Introduction of species particularly in the upper part with some species terminating below the top of the Zone. Listed below are species whose ranges end (Column A) or begin (Column B) in this Zone.

COLUMN A

Gambierina edwardsii
Latrobosporites ohaiensis
Ornamentifera sentosa
Proteacidites angulatus
Stereisporites regium
Tetracolporites verrucosus

COLUMN B

Banksiaeidites elongatus
Myrtaceidites mesonesus/parvus
Nothofagidites flemingii
Parvisaccites catastus
Proteacidites adenanthoides
P. annularis
P. incurvatus
P. tenuixinus

OCCURRENCE: Widespread in offshore portion of Gippsland Basin (Stover and Evans 1973); with equivalents probably present in the southwest onshore portion of the basin, based on the spore pollen lists given in Cookson & Dettmann (1959) and Traill (1968).

AGE: Middle and late Paleocene.

CORRELATIVES: *Gambierina edwardsii* Zonule of Harris (1971) is in part equivalent, and probably most of the localities referred to Microflora B by Cookson (1954).

Malvacipollis diversus ZONE

DIAGNOSTIC FEATURES: Base is defined by the first appearance of *Banksiaeidites arcuatus*, *Cupanieidites major/orthoteichus*, *Intratropipollenites notabilis*, *Liliacidites lanceolatus*, *Polycolpites esobalteus*, *Proteacidites grandis*, *P. leightonii*, *Schizocolpus marlinensis*, *Spinizonocolpites prominatus* and *Verrucosiporites kopukuensis*. Top of the Zone is indicated by the introduction of species diagnostic of the overlaying *Proteacidites asperopolus* Zone and by quantitative changes in the assemblages explained in the presentation of the *P. asperopolus* Zone.

OTHER FEATURES: A large number of species appear within the Zone of which the majority occur sporadically in the lower and middle part of the Zone and consistently in the upper part. These include, in addition to those shown in Fig. 3, *Anacolisidites acutulus*, *A. luteoides*, *Beaupreaidites elegansiformis*, *Kuylisporites waterbolckii*, *Milfordia homeopunctata*, *Proteacidites kopiensis*, *P. latrobensis*, *P. obscurus*, *P. reticuloscabratus* and *P. tuberculiformis*. Toward the top of the Zone another group of species appears which are

typically more common in younger Zones. These include *Dryptopollenites semilunatus*, *Eriopites crassixinus*, *Nothofagidites deminutus*, *N. goniatius*, *N. heterus*, *Proteacidites asperopolus*, *P. reticulatus* and *Santalumidites cainozoicus*. Only *Latrobosporites crassus*, *Nothofagidites endurus* and *Tricolpites gillii* terminate within the *Malvacipollis diversus* Zone.

OCCURRENCE: Fairly widespread in the offshore portion of the Gippsland Basin with reference sections given by Stover and Evans (1973).

AGE: Early Eocene.

CORRELATIVES: The Otway Basin *Cupanieidites orthoteichus* Zonule of Harris (1971) is in part equivalent to the *Malvacipollis diversus* Zone.

Proteacidites asperopolus ZONE

DIAGNOSTIC FEATURES: Base is defined by the initial occurrence of *Bombacacidites bombaxoides*, *Helicopites astrus*, *Liliacidites bainii*, *Myrtaceidites verrucosus*, *Proteacidites crassus* and *Sapotaceoidapollenites rotundus*. Zone is also characterized by the relatively high abundance of *Proteacidites asperopolus* and/or *P. pachypolus* (6% to 14%) and by *Haloragacidites harrisii* being more abundant than *Nothofagidites* spp. The relative abundance of *H. harrisii* to *Nothofagidites* spp. tends to be greatest in the lower part of the Zone with the difference in the relative abundance of the two pollen types diminishing gradually towards the top of the Zone. Top is delimited by the essentially contemporaneous termination of *Intratropipollenites notabilis*, *Malvacipollis diversus*, *Myrtaceidites tenuis*, *Proteacidites grandis*, and *P. ornatus*.

OCCURRENCE: Offshore portion of the Gippsland Basin with reference sections given by Stover and Evans (1973).

AGE: Early Eocene.

CORRELATIVES: The *Proteacidites confragosus* Zonule of Harris (1971) from the western Gambier embayment is possibly a correlative of the *Proteacidites asperopolus* Zone.

LOWER Nothofagidites asperus ZONE

The base of the Lower *Nothofagidites asperus* Zone was defined by Stover and Evans (1973) from offshore sections and because of the unconformity at the top of the Latrobe Group they were unable to propose palynologic criteria for the recognition of the upper boundary. The part of the Zone equivalent to the interval missing in offshore sections, was identified by Partridge (1971) in onshore wells, where the top of the Zone can also be seen expressed in a non-marine

sequence. Consequently, it is now possible not only to define the top but also to submit a more complete description of the Zone.

DIAGNOSTIC FEATURES: The base of the Zone is defined by the first appearance of 15 species listed below. Of these, the seven designated by asterisks are found only in the Lower *Nothofagidites asperus* Zone.

- **Anisotricolporites triplaxis*
- Foveotrilites balteus*
- **Gemmatricolporites gestus*
- Gothanipollis bassensis*
- Nothofagidites asperus*
- Nothofagidites falcatus*
- Nothofagidites vansteenisii*
- Periporopollenites vesicus*
- **Proteacidites recavus*
- **Proteacidites reflexus*
- Rugulatisporites trophus*
- **Tricolpites simatus*
- **Tricolpites thomasii*
- **Tricolporites angurium*
- Tricolporites leuros*

Equally diagnostic of the base of the Zone is the preponderance of *Nothofagidites* specimens in the assemblage. In addition, practically all of the species of *Nothofagidites* described by Cookson (1946, 1959) are represented. Owing to the drastic increase in *Nothofagidites*, there is a sharp reversal in the ratio of specimens of *Haloragacidites harrisii* to those of *Nothofagidites* spp. Because many of the species that begin in the Lower *Nothofagidites asperus* Zone are sparse or rare at the beginning of their ranges or in marginal marine sections, the 'harrisii reversal' affords a quantitative means for recognizing the base of the Zone.

An impressive number of species have their final occurrences at or near the top of the Zone. These include: 1, most of the species whose ranges are confined to the Lower *Nothofagidites asperus* Zone; 2, the species listed on Fig. 3 whose ranges are shown as stopping at the top of the Lower *N. asperus* Zone and 3, the following additional forms: *Proteacidites adenantoides*, *P. crassus*, *P. latrobensis*, *P. reticulatus*, *P. reticulosabratus*, *P. tuberculiformis*, *Simplicipollis meridianus* and *Tricolporites scabratus*.

OTHER FEATURES: Within the Lower *Nothofagidites asperus* Zone thirteen additional species appear. These are listed in Column A, given below. The first eight species listed occur nearly simultaneously and before the last five species listed. Prior to the incoming of the first eight forms in Column A the species listed in column B, also

given below, complete their vertical ranges. Based on the termination of these species plus the subsequent introduction of the species listed in Column A, the Lower *N. asperus* Zone can be divided locally into an upper and lower Subzone. Because the regional distribution of the Subzones has yet to be demonstrated, no formal names for them are proposed.

COLUMN A

- Aglaoreidia qualumis*
- Anacolosidites sectus*
- Gephyrapollenites calathus*
- Paripollis ochesis*
- Polycolpites reticulatus*
- Proteacidites stipplatus*
- Tricolporites sphaerica*
- Triorites magnificus*
- Foveotrilites palaequetrus*
- Proteacidites rectomarginis*
- Tricolporites retequetrus*
- Tripuripollenites chnosus*
- Verrucosisporites cristatus*

COLUMN B

- Anacolosidites acutullus*
- A. luteoides*
- Dryptopollenites semilunatus*
- Liliacidites bainii*
- Proteacidites alveolatus*
- P. asperopolus*
- P. incurvatus*
- P. kopiensis*
- P. pachypolus*
- P. tenuiexinus*
- Schizocolpus marlinensis*
- Spinizonocolpites prominatus*
- Tricolpites incisus*

COLUMN A: species that appear within the Lower *N. asperus* Zone.

COLUMN B: species that terminate within the Lower *N. asperus* Zone.

DISCUSSION: Although angiosperm pollen dominate palynomorph assemblages from the Lower *Nothofagidites asperus* Zone there is generally a slight increase in the relative abundance of gymnosperm pollen in this Zone over that in the preceding Zone. Among the angiosperm pollen the most conspicuous features are 1, the increased abundance of *Nothofagidites* spp., 2, the continual decrease in the prevalence of proteaceous pollen and 3, the greater diversity of small, generally anguloaperturate pollen such as *Gothanipollis bassensis*, *Tricolpites thomasii* and *T. simatus*. Considerable preservational and compositional differences are seen among the spore-pollen assemblages from this Zone—more so than

in any of the older Zones. In preservation, abundance and diversity the best assemblages are from the onshore sections and each of these conditions becomes poorer or decreases in offshore wells. There is, however, an increase in the amount of microplankton in assemblages from offshore sections.

OCCURRENCE: Onshore and offshore portions of the Gippsland Basin, and in the former the Zone is typically developed in Wurruck-1 well between 2898 and 3023 ft.

AGE: Middle and late Eocene.

CORRELATIVES: The *Proteacidites pachypolus* and *Triorites magnificus* Zonules of Harris (1971) are considered equivalent to this zone.

UPPER *Nothofagidites asperus* ZONE

DIAGNOSTIC FEATURES: The Zone occupies the interval between the last occurrence of *Triorites magnificus* as well as the other species whose ranges end at the top of the Lower *Nothofagidites asperus* Zone, and the first occurrence of *Cyatheacidites annulatus*. The Zone is characterized by *Proteacidites stipplatus*, which is rare in the underlying Zone but is the dominant species of *Proteacidites* in samples from this Zone, plus the first appearance of the species *Granodiporites nebulosus* and *Proteacidites tuberculatus*.

OTHER FEATURES: An increase in the frequency of occurrence of *Aglaoreidia qualunis*, *Proteacidites rectomarginis* and the last appearance of specimens of *Stereisporites (Tripunctisporis)* spp.

DISCUSSION: This Zone represents a transition assemblage between typical Eocene and Oligocene assemblages. The diversity of species in this Zone is low when compared with the other Zones, and most of the species recorded are long ranging Eocene to Oligocene forms. Also the spore-pollen assemblages obtained from clastic sediments are very similar to the assemblages obtained from the coals in this Zone, whereas in other Zones the clastic strata yield more diverse assemblages than the associated coals. This may be in part a reflection of the lithologies in this interval which consist predominantly of sands and thick coal seams. Some of the coal assemblages are unusual in containing very high percentages of specimens of *Phyllocladites mawsonii* (more than 80%).

OCCURRENCE: Onshore portion of the Gippsland Basin; assemblages indicative of this Zone occur in Wurruck-1 well between 2367 and 2817 ft.

AGE: Late Eocene into early Oligocene.

CORRELATIVES: The Zone is regarded as equivalent

to Taylor's (1966) planktonic foraminiferal Zonule K and the lower part of Zonule J.

Proteacidites tuberculatus ZONE

DIAGNOSTIC FEATURES: The base of the Zone is defined by the first appearance of *Cyatheacidites annulatus* and *Foveotriletes crater*; the top is marked by the last occurrence of *Foveotriletes palaequetrus*, *Kuylisporites waterbolkii* and *Tricolporites retequetrus* and the absence of species indicative of the overlying *Triporopollenites bellus* Zone.

OTHER FEATURES: Approximately 20 spore-pollen species have their last occurrence within this Zone, and based on these extinctions, a tripartite subdivision can be recognized locally. Because the subdivisions are determined by species terminations, without the sequential introduction of a meaningful number of species in successive intervals, no formal nomenclature for the subdivisions is proposed. Moreover, the six species that do appear within the *Proteacidites tuberculatus* Zone are sparse or rare. Distribution of forms whose ranges begin or end within this Zone are shown in Fig. 2.

Assemblages from the base of the *Proteacidites tuberculatus* Zone are further characterized by the consistent and frequently common occurrence of *Proteacidites rectomarginis*, *Foveotriletes crater*, *Verrucosisporites cristatus* and the nominate species. *Myrteacidites eucalyptoides* Cookson & Pike 1954 and *Chenopodopollis* spp. are first recorded from this part of the Zone, where they are rare. *Foveotriletes lacunosus* and *Cyathidites subtilis*, which occur initially and usually together in the middle subdivision, are also rare and *C. subtilis*, although distinctive, can be easily misidentified or overlooked. In the upper subdivision is recorded the first appearance of *Polyadopollenites myriosporites* and *Psilastephanocolporites micus*. These species are of uncertain stratigraphic value; the former because it is extremely rare, whereas the latter appears to be a facies fossil occurring almost exclusively in coals.

OCCURRENCE: Onshore portion of the Gippsland Basin; in the Latrobe Valley the Zone occurs in the clay below the Morwell No. 2 seam up into the Morwell No. 1A seam approximately 170 ft above the clay split between Morwell No. 1A and No. 1B seams.

AGE: Early Oligocene through early Miocene.

CORRELATIVES: The base of the zone is in the upper part of Taylor's (1966) planktonic foraminiferal Zonule J and the top is equated to the boundary between Zonules E and F, that is, the early-late Miocene boundary. The top of the

| SPECIES | PRE-P. TUBERCULATUS ZONE | PROTEACIDITES TUBERCULATUS ZONE | | | TRIPORO- POLLITES BELLUS ZONE |
|--|--------------------------------|---------------------------------|--------|-------|--|
| | | LOWER | MIDDLE | UPPER | |
| <i>Aglaoreidia qualumis</i> | | | | | |
| <i>Beaupreaidites verrucosus</i> | | | | | |
| <i>Concolpites leptos</i> | | | | | |
| <i>Granodiporites nebulosus</i> | | | | | |
| <i>Paripollis ochesis</i> | | | | | |
| <i>Parvisaccites catastus</i> | | | | | |
| <i>Proteacidites pseudomoides</i> | | | | | |
| <i>Rugulatisporites trophus</i> | | | | | |
| <i>Gothanipollis bassensis</i> | | | | | |
| <i>Ilexpollenites anguloclavatus</i> | | | | | |
| <i>Nothofagidites flemingii</i> | | | | | |
| <i>Nothofagidites goniatus</i> | | | | | |
| <i>Periporopollenites demarcatus</i> | | | | | |
| <i>Periporopollenites vesicus</i> | | | | | |
| <i>Proteacidites stipplatus</i> | | | | | |
| <i>Foveotrilites palaequetrus</i> | | | | | |
| <i>Kuylisporites waterbolckii</i> | | | | | |
| <i>Tricolporites retequetrus</i> | | | | | |
| <i>Cyatheacidites annulatus</i> | | | | | |
| <i>Foveotrilites crater</i> | | | | | |
| <i>Myrtacidites eucalyptoides</i> | | | | | |
| <i>Chenopodopollis</i> spp. | | | | | |
| <i>Cyathidites subtilis</i> | | | | | |
| <i>Foveotrilites lacunosus</i> | | | | | |
| <i>Polyadopollenites myriosporites</i> | | | | | |
| <i>Psilastephanocolporites micus</i> | | | | | |

FIG. 2—Distribution of selected spore-pollen species within the *Proteacidites tuberculatus* Zone.

middle subdivision of the *Proteacidites tuberculatus* Zone approximates the Oligocene—Miocene boundary.

Triporopollenites bellus ZONE

DIAGNOSTIC FEATURES: The base of the Zone is defined by the first appearance of the nominate species and of *Polypodiaceoisporites tumulus*, *Proteacidites symphyonemoides*, *Rugulatisporites micraulaxus*, *Symplocoipollenites austellus* and *Tubulifloridites antipodica*. The top is inadequately defined palynologically, but is provisionally taken as the first appearance of *Haloragacidites amolus*, which also corresponds to a marked decrease in the abundance of *Nothofagidites* specimens.

OTHER FEATURES: Species characteristic of the

Triporopollenites bellus Zone because of their general increase in abundance are *Milfordia homeopunctata*, *Gephyrapollenites calathus* and *Myrtacidites eucalyptoides*. The ranges of *Herkosporites elliotii* and *Proteacidites recto-marginis* end whereas the range of *Haloragacidites haloragoides* begins within the Zone.

DISCUSSION: Specimens of *Nothofagidites* spp. are still abundant in the lower part of the Zone, and become gradually less common and are represented by fewer species towards the top. Gymnosperm pollen are also less diverse and abundant than in the *Proteacidites tuberculatus* Zone; in contrast, angiosperm pollen increase slightly in diversity, especially tricolporate forms and those of *Myrtacidites* spp.

OCCURRENCE: Onshore portion of the Gippsland

Basin. Localities at which the Zone has been identified include the Yallourn Open Cut from the clay at the floor of the cut to 80 ft above the clay and Wurruk-1 well from 426 to 888 ft.

AGE: Late Miocene, possibly into Pliocene.

CORRELATIVES: The *Triporopollenites bellus* Zone is equivalent to the interval covered by Taylor's (1966) planktonic foraminiferal Zonules E through B and possibly Zonule A.

SUMMARY

Palynologically, no other Late Cretaceous through Miocene section in Australia has been studied as completely and in such detail as that in the Gippsland Basin. Within the approximately 7000 feet of non-marine strata comprising the Latrobe Group and the Latrobe Valley Coal Measures, ten biostratigraphic Zones are recognized. These include the six Zones delimited by Stover & Evans (1973) plus the Lower *Nothofagidites asperus*, Upper *Nothofagidites asperus*, *Proteacidites tuberculatus* and *Triporopollenites bellus* Zones. The zonation expresses an essentially uninterrupted though gradually changing sequence of palynologic assemblages and is based on the vertical ranges of about 150 spore-pollen species and on the compositional consistency of the palynomorph assemblages from each Zone. The ranges of the 65 new species described in this paper together with an additional 35 previously described forms are shown on Fig. 3. This range chart emphasizes the species most useful for subdividing the middle Eocene through Miocene section and is, therefore, supplemental to the range chart in Stover & Evans (1973) which stressed those species of stratigraphic importance in the Late Cretaceous through early Eocene.

The Late Cretaceous and Tertiary spore-pollen zonation for the Gippsland Basin coupled with those for the Early Cretaceous (Dettmann, 1963; Evans, 1966) and for the Late Cretaceous (Dettmann & Playford, 1969) afford a biostratigraphic framework for southeastern Australia covering a substantial portion of the stratigraphic column. Just as the zonations for the Cretaceous have proved invaluable for identifying, dating and interpreting comparable sections in other basins, it is anticipated that the Gippsland Basin zonation will prove equally relevant in nearby basins, and at the very least will serve as a comparison or reference section for future palynologic studies of Tertiary intervals in more distant regions. Undoubtedly, many of the species described and illustrated in the next section will be found in other basins, and as more information on the geographic distribution and the stratigraphic occurrences of these forms becomes available, a better under-

standing of the Tertiary palynology of Australia will emerge.

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DESCRIPTIVE PALYNOLOGY

This section presents the descriptions for ten new form genera and sixty-five new form species together with selected synonyms, revised descriptions and comments on previously described species. Stratigraphic ranges given for each species are those for the Gippsland Basin only. The locations of holotypes, neotypes and lectotypes are included with the descriptions; those for paratype and hypotypes are given in the Register of Illustrated Specimens at the end of the paper. Type specimens for many of the species described before 1955 were never designated and because the preparations containing practically all of the illustrated specimens have been located recently lectotypes are selected for those species dealt with here and some are re-illustrated. The 'P' numbers given for all the illustrated specimens and for the lectotypes designated without illustration in the text are those of the palaeontological collections in the National Museum of Victoria, Melbourne.

Trilete Spores

Genus *Baculatisporites* Thomson & Pflug 1953
Baculatisporites disconformis Stover, n. sp.

(Pl. 13, fig. 8)

DESCRIPTION: Amb circular to subcircular, commonly modified by folding. Spore wall slightly less than 1 μ

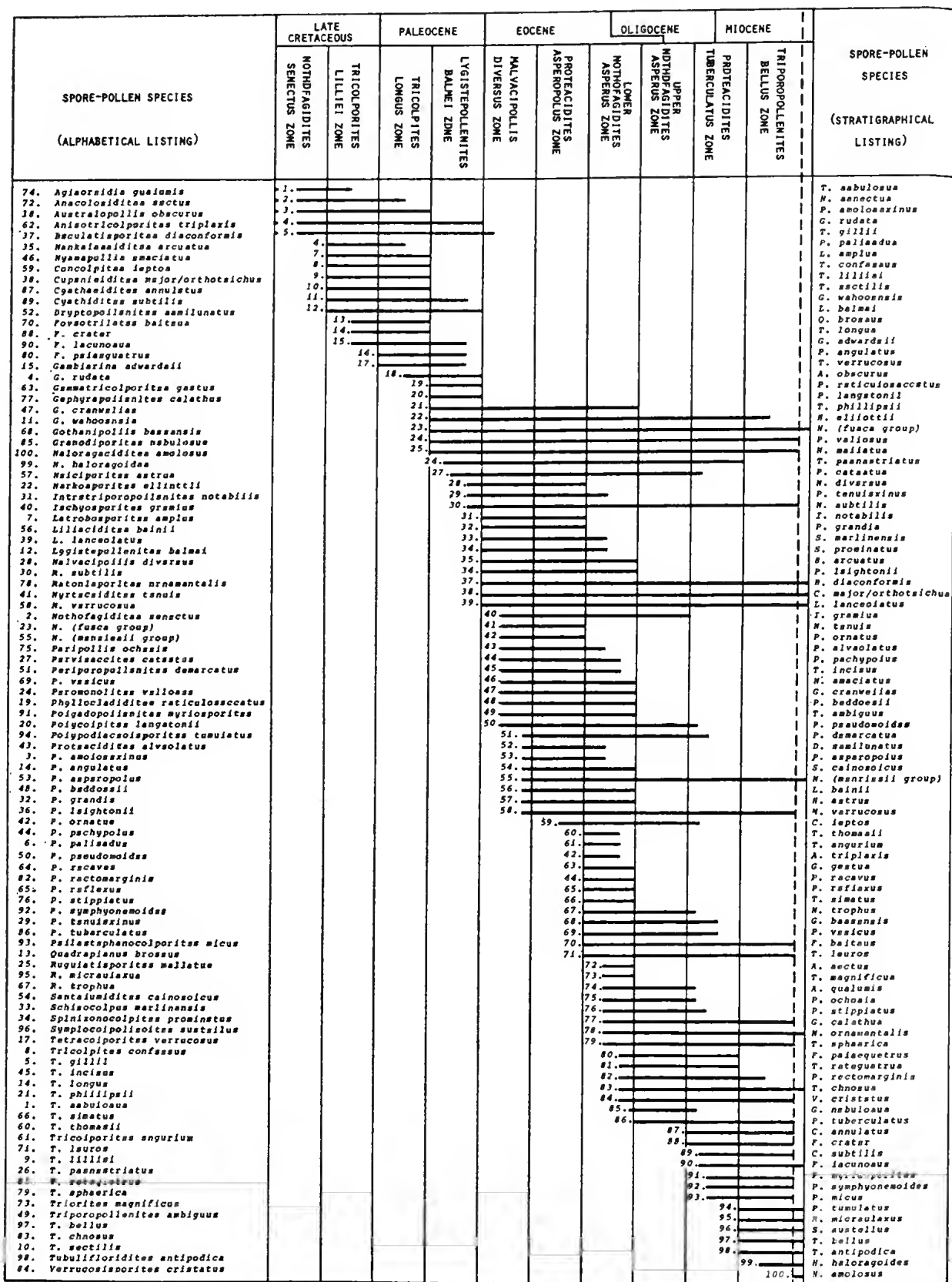


FIG. 3—Ranges of selected spore-pollen species in the Gippsland Basin.

thick, ornamented with discrete or fused, irregularly shaped protruberances 1 to 2 μ high, circular, roundly polygonal or sinuously elongate in plan view, length varies from 1 to 2.5 μ for individual projections, up to 9 μ for fused projections. Trilete rays 20 to 25 μ long, may be bordered by low, narrow, irregular marginal ridges. Diameter 40 (50) 55 μ based on 12 favorably oriented specimens.

COMPARISON: *Baculatisporites disconformis* differs from *B. comaumensis* (Cookson) Potonié 1956 by having generally larger, mainly non-equidimensional projections and a greater proportion of fused projections which in small areas tend to form short ridge-like structures. In *B. comaumensis* the ornamentation consists of equidimensional bacula and a few setae and clavae that are separate and randomly disposed.

HOLOTYPE: Specimen on slide P28050, 53 μ in diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 4648 ft, *Malvacipollis diversus* Zone, early Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through *Triporopollenites bellus* Zone, early Eocene through Miocene.

REMARKS: Considerable variability was observed in the size, shape, density and distribution of the projections and, of course, in the outline of the spores because of folding. A large number of specimens were split, most frequently at the ends of the trilete rays.

Genus *Cyatheidites* Cookson 1947 emended
Partridge

1947 *Trilites* (*Cyatheidites*) Cookson, p. 136.

TYPE SPECIES: *Cyatheidites annulatus* Cookson 1947, designated by Potonié (1956, p. 62).

DIAGNOSIS (Emended): Spores trilete, cingulate, spore wall two layered; inner layer thin, attached proximally and equatorially, separated distally from thick outer wall layer. Proximal surface with various positive types of ornamentation which coalesce adjacent to the trilete rays to form flat contact areas.

COMPARISON: Potonié (1956) and Krutzsch (1959, 1967) compared *Cyatheidites* to *Cingulatisporites* Thomson 1953, to *Polypodiaceosporites* Potonié 1951 and to *Densoisporites* Weyland & Krieger 1953. *Cyatheidites* differs from the first two by having the two wall layers separated distally and from the last by having the inner wall layer appressed equatorially as well as proximally.

Cyatheidites annulatus Cookson 1947
(Pl. 13, figs. 5, 6)

1947 *Trilites* (*Cyatheidites annulatus*) Cookson p. 153, Pl. 15, figs. 53-55.

1957 *Cyathea annulata* (Cookson) Cookson, p. 45, Pl. 9, figs. 4, 5.

1967 *Cyatheidites annulatus* Cookson, Cookson & Cranwell, p. 208, Pl. 3, figs. 7, 8.

1969 ———, Cookson Fasola, p. 12, Pl. 2, fig. 3.

DESCRIPTION (Revised): Amb subcircular to subtriangular, apices broadly rounded; distal surface

moderately convex, proximal surface flat to shallowly pyramidal. Spore wall two layered, inner layer 1 to 2 μ thick, separated distally from outer layer, latter 3 to 5 μ thick, distal surface with circular or irregularly shaped flat based foveolae or fossulae which may form a negative reticulum. Proximal surface granulate to verrucate, ornamentation coalesced adjacent to trilete rays to form flat, delicately foveolate to fossulate contact areas of variable size and shape. Cingulum psilate, 1/5 to 1/4 spore radius in width, outer margin smooth to irregular, profile semicircular. Dimensions, 35 (56) 65 μ in diameter, 28 specimens measured.

STRATIGRAPHIC RANGE: *Proteacidites tuberculatus* Zone through the *Triporopollenites bellus* Zone, early Oligocene through Miocene. Cookson (1957) reports *C. annulatus* from the Pliocene of Queensland; Cookson & Cranwell (1967) and Fasola (1969) record it from the Eocene of Chile.

Genus *Cyathidites* Couper 1953
Cyathidites subtilis Partridge, n. sp.
(Pl. 13, figs. 1, 2)

DESCRIPTION: Amb triangular, apices broadly rounded, sides straight to slightly concave, outline biconvex in equatorial view. Trilete rays extend to apices or nearly so. Spore wall 1 to 2.5 μ , granulate, granulae up to 1 μ in diameter, dense, area covered by granulae greater than intervening area so that spore wall may appear reticulate at focus levels near or at the bases of the granulae. Dimensions, 22 (35) 44 μ in diameter, 26 specimens measured.

COMPARISON: *Cyathidites subtilis* differs from *C. minor* Couper 1953 by having a granulate rather than a psilate spore wall.

HOLOTYPE: Specimen on slide P29714, 38 μ in diameter.

TYPE LOCALITY AND STRATA: Lakes Entrance Oil Shaft at 352 ft, Gippsland Limestone, *Triporopollenites bellus* Zone, late Miocene.

STRATIGRAPHIC RANGE: Just above the base of the *Proteacidites tuberculatus* Zone and through the *Triporopollenites bellus* Zone, late Oligocene through Miocene.

Genus *Foveotrilites* van der Hammen ex Potonié
1956

Foveotrilites balteus Partridge, n. sp.
(Pl. 14, fig. 7)

DESCRIPTION: Amb convexly triangular, apices narrowly rounded, distal surface moderately convex, proximal surface pyramidal. Trilete rays extend nearly to spore margin, lips narrow, up to 3 μ in height. Proximal surface with concave folds (kyrtome) between trilete rays, folds continue around equatorial ends of trilete. Spore wall 1.5 to 2 μ interradially, up to 3 μ at apices. Surface foveolate, foveolae circular to elliptical, occasionally coalesced to form short, curved fossulae on distal surface where foveolae tend to be denser, foveolae least developed adjacent to trilete. Dimensions, 29 (43) 50 μ in diameter, 14 specimens measured.

COMPARISON: *Foveotrilites balteus* differs from *F. lacunosus* Partridge (this paper) by being larger, and by having a thicker spore wall, and a kytome developed around the trilete.

HOLOTYPE: Specimen on slide P29828. 50 μ in diameter.

TYPE LOCALITY AND STRATA: Rosedale-1 well, core 13 at 1854-1857 ft, *Proteacidites tuberculatus* Zone, early Oligocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone through *Triporopollenites bellus* Zone, middle Eocene through Miocene.

***Foveotrilites crater* Partridge n. sp.**
(Pl. 14, fig. 1-3)

DESCRIPTION: Amb triangular, apices moderately rounded, sides slightly concave. Trilete 2/3 to 3/4 spore radius. Spore wall 1 to 3 μ thick, foveolate; foveolae circular, 0.5 to 4 μ in diameter, density of foveolae variable from high density with smaller foveolae to low density with larger foveolae. A row of small foveolae may occur along trilete margins. Dimensions, 20 (29) 35 μ , 32 specimens measured.

COMPARISON: Specimens having the larger foveolae resemble *Kuylisporites waterbolkii* Potonié 1956, but lack the large interradial foveolae characteristic of the latter species. Specimens having smaller foveolae differ from *Foveotrilites lacunosus* Partridge n. sp. in shape and in having more closely spaced and sharply delimited foveolae.

HOLOTYPE: Specimen on slide P29723, 30 μ in diameter.

TYPE LOCALITY AND STRATA: Morwell, Victoria; clay split between Morwell 1A and 1B seams, north wall of Morwell Open Cut, *Proteacidites tuberculatus* Zone, early Miocene.

STRATIGRAPHIC RANGE: *Proteacidites tuberculatus* Zone through *Triporopollenites bellus* Zone, early Oligocene through Miocene.

***Foveotrilites lacunosus* Partridge, n. sp.**
(Pl. 14, fig. 6)

DESCRIPTION: Amb triangular, apices moderately to narrowly rounded, sides convex; distal surface convex, proximal surface pyramidal, elevation slight. Trilete rays 3/4 to 4/5 spore radius, marginal lips narrow. Spore wall 1 to 2.5 μ thick, proximal surface psilate, distal surface with poorly delimited, shallow foveolae 0.5 to 1.5 μ in diameter. Dimensions, equatorial diameter 30 (34) 41 μ , 14 specimens measured.

COMPARISON: This species differs from *Foveotrilites crater* by having less well defined foveolae, a convexly rather than a concavely triangular amb, and an unornamented proximal surface.

HOLOTYPE: Specimen on slide P29847, 38 μ in diameter.

TYPE LOCALITY AND STRATA: Lakes Entrance Oil Shaft at 492 ft, Gippsland Limestone, *Triporopollenites bellus* Zone, late Miocene.

STRATIGRAPHIC RANGE: *Proteacidites tuberculatus* Zone through *Triporopollenites bellus* Zone, late Oligocene through Miocene.

***Foveotrilites palaequetrus* Partridge, n. sp.**
(Pl. 14, fig. 4, 5)

DESCRIPTION: Amb triangular to vaguely hexagonal, sides straight, recessed between bluntly truncated apices. Trilete rays full spore radius, or nearly so, spore wall commonly split at ends of rays. Spore wall 1.5 to 2 μ thick, foveolate; foveolae poorly delimited, shallow, circular on distal surface and 0.5 to 1.5 μ in diameter, elliptical on proximal surface and up to 3 μ long; distal polar area generally smooth. Dimensions, equatorial diameter 30 (35) 42 μ 8 specimens measured.

COMPARISON: This species differs from *Foveotrilites lacunosus* by having recessed interradial margins and some ornamentation on the proximal surface.

HOLOTYPE: Specimen on slide P29734, 35 μ in diameter.

TYPE LOCALITY AND STRATA: Lakes Entrance Oil Shaft at 1188 ft, Lakes Entrance Formation, *Proteacidites tuberculatus* Zone, early Oligocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone through *Proteacidites tuberculatus* Zone, late Eocene through early Miocene.

Genus *Herkosporites* Stover, n. gen.

Type Species: *Herkosporites elliottii* Stover, n. sp., here designated.

DIAGNOSIS: Spores trilete, amb circular to roundly triangular, proximal surface ornamented only adjacent to trilete rays, distal surface variously ornamented, fimbriate and spinate on known species. Trilete rays greater than 2/3 spore radius, lips raised, membranous. Affinity unknown.

COMPARISON: *Herkosporites* differs from *Ceratosporites* Cookson & Dettmann 1958 by having ornamentation adjacent to the trilete and from *Styxisporites* Cookson & Dettmann 1958 by lacking an equatorial flange.

***Herkosporites elliottii* Stover, n. sp.**
(Pl. 13, fig. 7)

DESCRIPTION: Spores trilete, amb subcircular to roundly triangular; trilete distinct, rays extend to equatorial margin or nearly so, margins of rays thickened; thickenings give rise to thin, hylate membranous structure projecting to 5 μ above the proximal surface. Proximal surface psilate in interradial areas, radial areas adjacent to trilete ridges with row of spines on each side of trilete rays. Distal surface spinate; spines to 5 μ in length, about 1 μ in diameter, sides very gently tapered, tips blunt to pointed, evenly distributed, space between adjacent spines 2.5 μ to 4 μ ; spore wall about 1 μ thick. Dimensions, 37 (42) 45 μ in diameter, exclusive of spines, 14 specimens measured.

COMPARISON: *Herkosporites elliottii* differs from *Ceratosporites equalis* Cookson & Dettmann 1958 by having ornamentation locally on the proximal surface.

HOLOTYPE: Specimen on slide P29858, 40 μ in diameter, exclusive of spines.

TYPE LOCALITY AND STRATA: Loy Yang-842 bore at 483-486 ft, *Proteacidites tuberculatus* Zone, early Oligocene.

STRATIGRAPHIC RANGE: *Lygistepollenites balmei* Zone through most of the *Triporopollenites bellus* Zone, middle Paleocene into late Miocene.

Genus *Ischyosporites* Balme 1957
Ischyosporites gremius Stover, n. sp.
 (Pl. 14, fig. 8)

DESCRIPTION: Amb convexly triangular, proximal surface pyramidal, distal surface strongly convex; trilete distinct, rays extend 1/2 to 3/4 spore radius. Proximal surface smooth, distal surface foveo-reticulate; lumen circular to elliptical, 5-7 μ in diameter, moderately spaced, occasional adjacent lumen coalesced. Spore wall 2 to 3 μ thick interrally, up to 4.5 μ thick radially. Dimensions, 49 (57) 62 μ in diameter, 23 specimens measured.

COMPARISON: *Ischyosporites gremius* differs from *I. punctatus* Cookson & Dettmann 1958 by having a smooth rather than a punctate proximal surface and from *I. crateris* Balme 1957 by having smaller lumina, a shorter trilete and a thinner spore wall.

HOLOTYPE: Specimen on slide P28057, 52 x 58 μ in diameter.

TYPE LOCALITY AND STRATA: Bass-1 well at 5400 ft, *Malvacipollis diversus* Zone, early Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through the Upper *Nothofagidites asperus* Zone, early Eocene into the early Oligocene.

Genus *Kuylisporites* Potonié 1956
Kuylisporites waterbolkii Potonié 1956
 (not illustrated)

1955 *Hemitelia* type, Kuyl, Muller & Waterbolk, Pl. 1, fig. 7.

1956 *Kuylisporites waterbolkii*, Potonié, p. 36, Pl. 4, fig. 36.

1973 ———, Potonié, Stover & Evans (in press).

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through the *Proteacidites tuberculatus* Zone, early Eocene to early Miocene.

Genus *Latrobosporites* Harris 1965

Type Species: *Latrobosporites crassus* Harris 1965, monotypic when proposed.

REMARKS: Examination of trilete spores from the lower portion of the Latrobe Group (*Tricolporites lilliei* through the *Lygistepollenites balmei* Zones) indicates that forms with hamulate ornamentation tend to occur most consistently within this interval. Hamulate spores have been assigned to different form genera on relatively minor dissimilarities in the

widths and completeness of an equatorial structure present on some but not all species. We believe the Gippsland Basin specimens belong to *Latrobosporites* Harris 1965 which is characterized by having a hamulate ornamentation that may be developed more coarsely on the distal than the proximal surface and by lacking crassitudes or by having only slight increases in the thickness of the spore wall in the interrally areas. The two species cited below are here transferred to *Latrobosporites* and selected synonyms are given for these forms.

Latrobosporites amplus (Stanley) Stover, n. comb.
 (not illustrated)

1965 *Hamulatisporis amplus* Stanley, p. 242, Pl. 29, figs. 1-6.

1968 *Camerozonosporites amplus* (Stanley) Dettmann & Playford, p. 79, Pl. 7, figs. 1-3.

STRATIGRAPHIC RANGE: *Tricolporites lilliei* and *Tricolpites longus* Zones, Late Cretaceous to early Paleocene, possibly middle Paleocene.

Latrobosporites crassus Harris
 (not illustrated)

1965 *Latrobosporites crassus* Harris, p. 18, Pl. 25, figs. 8, 9; Pl. 26, fig. 1.

COMMENTS ON HOLOTYPE: The distinctive hamulate ornamentation pattern is coarser and more clearly defined on the distal surface, with the angular rugulae and intervening grooves being smaller and narrower on the proximal surface.

STRATIGRAPHIC RANGE: *Tricolpites longus* Zone into *Malvacipollis diversus* Zone, early Paleocene into early Eocene.

Latrobosporites ohaiensis (Couper) Stover, n. comb.
 (not illustrated)

1953 *Trilites ohaiensis* Couper, p. 30, Pl. 3, fig. 23.
 1960 ——— Couper, Couper, p. 41, Pl. 2, figs. 7, 8.

1968 *Camerozonosporites ohaiensis* (Couper) Dettmann & Playford, p. 80, Pl. 7, figs. 6, 7.

1973 ——— (Couper) Dettmann & Playford, Stover & Evans (in press)

STRATIGRAPHIC RANGE: *Tricolporites lilliei* Zone into the *Lygistepollenites balmei* Zone, Late Cretaceous to middle Paleocene.

Genus *Matonisporites* Couper emended Dettmann 1963

Matonisporites ornamentalis (Cookson) Partridge, n. comb.
 (Pl. 13, figs. 3, 4)

1947 *Trilites ornamentalis* Cookson, p. 136, 137, Pl. 16, figs. 63, 64 and *T. cf. ornamentalis*, Pl. 16, fig. 65.

DESCRIPTION (Revised): Amb triangular, apices moderately rounded, interrally margins straight to slightly concave, convex in flattened specimens. Trilete rays straight, extend to inner margin of spore wall. Spore wall 1 to 2 μ thick proximally and interrally, 3 to 5 μ thick apically, 3 μ thick distally; wall

may have thickened bands 3 to 8 μ wide adjacent to trilete, proximal surface smooth, distal surface smooth, or with low irregular ruguloid thickenings. Dimensions, 28 (41) 55 μ in diameter, 28 specimens measured.

STRATIGRAPHIC RANGE: From within the Lower *Nothofagidites asperus* Zone through the *Triporepollenites bellus* Zone, late Eocene through Miocene.

Genus Ornamentifera Bolkhovitina 1966

Ornamentifera sentosa Dettmann & Playford 1968
(not illustrated)

1968 *Ornamentifera sentosa* Dettmann & Playford, p. 78, 79, Pl. 6, figs. 9-12.

1973 ——— Dettmann & Playford, Stover & Evans (in press).

STRATIGRAPHIC RANGE: *Tricolporites lilliei* Zone into the *Lygistepollenites balmei* Zone, Late Cretaceous to middle Paleocene.

Genus Polypodiaceosporites Potonié 1951

Polypodiaceosporites tumulatus, Partridge, n. sp.
(Pl. 16, fig. 4)

DESCRIPTION: Amb triangular, apices broadly rounded, sides slightly concave; in equatorial view distal surface convex to broadly V-shaped, proximal surface flat to obtusely arched. Trilete rays about 1/2 or more of spore radius, do not reach spore margin, bordered by thickened bands 2 to 3 μ wide and vague, discontinuous, low elevations in the contact areas, remainder of proximal surface psilate. Distal surface with verrucae of 2 to 3 μ in diameter in the marginal areas; distal polar area with larger verrucae or with flat, irregular rugulae. Cingulum psilate, 3 to 5 μ wide, of constant width or slightly narrower around apices. Dimensions, 32 (39) 44 μ in diameter, 18 specimens measured.

COMPARISON: The new species differs from *Polypodiaceosporites obscurus* Harris 1965 by having a wider cingulum and a non-rugulate proximal surface.

HOLOTYPE: Specimen on slide P29780, 43 μ in diameter.

TYPE LOCALITY AND STRATA: Wurruk-1 well at 426 ft, *Triporepollenites bellus* Zone, late Miocene.

STRATIGRAPHIC RANGE: *Triporepollenites bellus* Zone only, late Miocene.

Genus Rugulatisporites Thomson & Pflug 1953

Rugulatisporites mallatus Stover, n. sp.
(Pl. 15, fig. 1)

1965 *Convolutisporites* sp. indent. Harris, Pl. 25, fig. 13.

1973 *Rugulatisporites* sp. A, Stover & Evans (in press)

DESCRIPTION: Amb convexly triangular. Proximal and distal surfaces densely ornamented with short, discontinuous, sinuous ridges; crests of ridges blunt, gently rounded, cross section of ridges mushroom shaped. Ridges adjacent to trilete linear and parallel to rays. Trilete indistinct, deeply incised, rays straight,

extend 3/4 to full spore radius. Ridges about 2 to 4 μ wide at crests, distance between ridges 1 μ or less. Dimensions, 36 (42) 47 μ in diameter, 20 specimens measured.

COMPARISON: No species with similarly shaped ridges is known.

HOLOTYPE: Specimen on slide P28050, 40 μ in diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 4648 ft, *Malvacipollis diversus* Zone, early Eocene.

STRATIGRAPHIC RANGE: *Lygistepollenites balmei* Zone through *Triporepollenites bellus* Zone, middle Paleocene through late Miocene.

Rugulatisporites micraulaxus Partridge, n. sp.
(Pl. 15, fig. 2, 3)

DESCRIPTION: Amb roundly triangular to subcircular. Spore wall 1.5 to 3 μ thick, obvermiculate to rugulate on proximal and distal surfaces. Ornamentation varies from ridges 1.5 to 3 μ wide, flat or curved distally intervening areas 0.5 to 1 μ wide, discontinuous to ridges 0.5 to 1 μ wide, pointed or rounded distally, intervening areas 1 to 3 μ wide, interconnected. Trilete rays approximately 4/5 spore radius, margined by unsculptured area 2 to 3 μ wide. Dimensions, 28 (36) 45 μ in diameter, 21 specimens measured.

COMPARISON: Consult comparison for *Rugulatisporites trophus*.

HOLOTYPE: Specimen on slide P29796, 37 μ in diameter.

TYPE LOCALITY AND STRATA: Wurruk-1 well at 426 ft, *Triporepollenites bellus* Zone, late Miocene.

STRATIGRAPHIC RANGE: *Triporepollenites bellus* Zone, late Miocene.

Rugulatisporites trophus Partridge, n. sp.
(Pl. 15, fig. 4)

DESCRIPTION: Amb subcircular, outline elliptical in equatorial view. Spore wall 5 to 9 μ thick (usually 7 to 8 μ), rugulae 2 to 10 μ wide, most frequently 2 to 5 μ wide, distribution random, crests flat to broadly rounded. Trilete indistinct, rays 3/4 or more of spore radius, rays may be margined by straight rugulae. Dimensions 43 (53) 62 μ in diameter, 14 specimens measured.

COMPARISON: *Rugulatisporites trophus* differs from *R. micraulaxus* Partridge by having wider rugulae, a thicker spore wall and a greater diameter. The former differs from *R. mallatus* Stover by having flat to gently rounded rugulae that are not mushroom shaped in cross section and a thicker spore wall.

HOLOTYPE: Specimen on slide P29794, 59 μ in diameter.

TYPE LOCALITY AND STRATA: Wurruk-1 well at 2898 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone into the lower part of the *Proteacidites tuberculatus* Zone, middle Eocene into early Oligocene.

Genus *Stereisporites* Pflug 1953
Stereisporites (*Tripunctisporis*) sp.
 (not illustrated)

1973 *Stereisporites* (*Tripunctisporis*) sp. Stover & Evans (in press).

REMARKS: Krutzsch (in Doring et al, 1966) proposed the subgenus *Tripunctisporis* for sphagnoid spores which have three triangularly arranged, distal, polar foveae or punctae. At the same time he defined and illustrated 10 new species from the Late Cretaceous (Senonian)—Paleocene of Europe. Attempts to assign Australian specimens to one or more of Krutzsch's species were unsuccessful owing mainly to the overlapping characteristics of many forms and the instability of morphologic features of supposed taxonomic value. Because too few specimens of this relatively uncomplex form were assembled to adequately evaluate species in terms of variability, the Australian specimens are recorded under the heading shown above.

STRATIGRAPHIC RANGE: *Tricolpites longus* Zone through the Upper *Nothofagidites asperus* Zone, Paleocene to early Oligocene.

Stereisporites regium (Drozastichich) Drugg 1967
 (not illustrated)

1967 *Sphagnum regium* Drozastichich in Samoilovich et al p. 18, Pl. 2, figs. 1-3.

1965 ——— Dorzastichich, Stanley, p. 238, Pl. 27, figs. 12-17.

1967 *Stereisporites regium* (Drozastichich) Drugg, p. 37, Pl. 6, fig. 20.

1973 ——— (Drozastichich) Drugg, Stover & Evans (in press).

STRATIGRAPHIC RANGE: Upper part of *Tricolpites lilliei* Zone into the *Lygistepollenites balmei* Zone, Late Cretaceous to middle Paleocene, possibly into the late Paleocene.

Genus *Verrucosiporites* Potonié & Kremp 1955
Verrucosiporites kopukuensis (Couper) Stover, n. comb.
 (Pl. 16, figs. 2, 3)

1960 *Trilites kopukuensis* Couper, p. 42, Pl. 3, figs. 1, 2.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through *Tripoporollenites bellus* Zone, early Eocene through Miocene.

REMARKS: The absence of apical thickenings precludes retention of this species in *Trilites* as emended by Dettmann (1963), and because it possesses discrete verrucae, assignment to *Verrucosiporites* is appropriate. Although the ornamentation is mainly verrucate, the size, shape and density of the verrucae are variable and on some specimens granulae or gemmae are also present. The verrucae vary from circular to polygonal, are usually so closely spaced that similar size verrucae could not be placed between those already present. On some specimens the space between the verrucae is so close that a negative reticulum is formed, whereas on other specimens, the verrucae

are rather widely spaced with the intervening areas filled by granulae.

The equatorial outline varies from nearly circular to concavely triangular, and in size the specimens are from 65 to 170 μ in diameter. Specimens from the older end of the range tend to be smaller and less variable than those from the younger end of the range and broken specimens are common components in some assemblages.

Verrucosiporites cristatus Partridge, n. sp.
 (Pl. 15, fig. 5)

DESCRIPTION: Amb convexly triangular, commonly modified by folding, specimens usually flattened along polar axis. Trilete 2/3 to nearly full spore radius, without lips. Spore wall 1.5 to 4 μ thick, exclusive of ornamentation, latter composed of discrete, closely spaced capilli or filiform processes. Bases of processes generally constricted, distal ends flared with an irregular outline, processes 7 to 8 μ wide, up to 7 μ high, tips rounded or digitate. Spore wall between processes smooth or irregularly roughened. Dimensions, equatorial diameter 60 (82) 95 μ , 11 specimens measured.

COMPARISON: This species differs from *Verrucosiporites kopukuensis* (Couper) Stover (this paper) by having more irregularly shaped projections.

HOLOTYPE: Specimen on slide P29804, 70 μ in diameter.

TYPE LOCALITY AND STRATA: Lakes Entrance Oil Shaft at 1188 ft, Lakes Entrance Formation, *Proteacidites tuberculatus* Zone, early Oligocene.

STRATIGRAPHIC RANGE: Within the Lower *Nothofagidites asperus* Zone through the *Tripoporollenites bellus* Zone, late Eocene through Miocene.

Monolete spores

Genus *Peromonolites* Couper 1953
Peromonolites densus Harris 1965
 (not illustrated)

1965 *Peromonolites densus* Harris, p. 84, Pl. 24, figs. 3-5.

1973 ——— Harris, Stover & Evans (in press).

STRATIGRAPHIC RANGE: *Lygistepollenites balmei* Zone through the *Tripoporollenites bellus* Zone, middle Paleocene through Miocene.

Peromonolites vellosus Partridge, n. sp.
 (Pl. 15, fig. 6; Pl. 16, fig. 1)

DESCRIPTION: Amb elliptical to straight sided with rounded ends, outline plano-convex or concavo-convex in lateral view. Spore wall two layered, inner layer 1.5 to 2 μ thick, psilate; outer layer 3 to 4 μ thick composed of a basal portion less than 1 μ to slightly more than 1 μ thick and an outer, fibrous, mat-like mass imparting a furry appearance to the spores; two wall layers may be conspicuously separated from each other or they may be closely appressed. Monolete in psilate inner layer of flat or concave surface, length greater than 3/4 spore length. Dimensions,

length 32 (41) 52 μ , width 22 to 40 μ , 27 specimens measured.

COMPARISON: *Peromonolites vellosus* differs from *P. densus* Harris 1965 by having a mat-like rather than an irregularly folded or wrinkled outer layer. The latter is also thicker than that on *P. densus*.

HOLOTYPE: Specimen on slide P29795, 45 x 33 μ overall, inner wall layer 36 x 25 μ .

TYPE LOCALITY AND STRATA: Glencoe-4 well at 280 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: *Lygistepollenites balmei* Zone through the *Triporopollenites bellus* Zone, middle Paleocene to late Miocene.

Bisaccate Pollen

Genus *Lygistepollenites* Stover & Evans 1973

Lygistepollenites balmei (Cookson) Stover & Evans 1973
(not illustrated)

1957 *Dacrydiumites balmei* Cookson, p. 46, Pl. 9, figs. 11-14.

1965 ——— Cookson, Harris, p. 87, Pl. 26, fig. 17.
1973 *Lygistepollenites balmei* (Cookson) Stover & Evans (in press).

STRATIGRAPHIC RANGE: *Tricolporites lilliei* Zone through the *Lygistepollenites balmei* Zone, Late Cretaceous through Paleocene.

Lygistepollenites ellipticus (Harris) Stover & Evans 1973
(not illustrated)

1965 *Dacrydiumites ellipticus* Harris, p. 87, Pl. 26, figs. 20, 21.

1973 *Lygistepollenites ellipticus* (Harris) Stover & Evans (in press).

STRATIGRAPHIC RANGE: *Lygistepollenites balmei* Zone, middle and late Paleocene.

Lygistepollenites florinii (Cookson & Pike) Stover & Evans 1973
(not illustrated)

1953 *Dacrydiumites florinii* Cookson & Pike, p. 479, Pl. 3, figs. 20-35.

1965 ——— Cookson & Pike, Harris, p. 87, Pl. 26, fig. 18.

1973 *Lygistepollenites florinii* (Cookson & Pike) Stover & Evans (in press).

STRATIGRAPHIC RANGE: *Lygistepollenites balmei* Zone through the *Triporopollenites bellus* Zone, middle Paleocene through Miocene.

Genus *Parvisaccites* Couper 1958
Parvisaccites catastus Partridge, n. sp.
(Pl. 16, fig. 5, 6)

DESCRIPTION: Body elliptical, longer than wide, exine finely infrareticulate, 1.5 to 2 μ proximally, thinner distally; tenuitas thin and usually split, width 8 to 10 μ . Sacci pendant, broadly elliptical in polar view, more or less semicircular in lateral view, proximal roots equatorial or nearly so, distal roots margin

tenuitas; sacci infrareticulate, pattern somewhat radial from distal roots, denser and more distinctly reticulate equatorially and proximally, mesh coarsest at extremities. Outer surface of sacci smooth. Dimensions, overall length 35 (47) 40 μ , 15 specimens measured.

COMPARISON: *Parvisaccites catastus* differs from the type species, *P. radiatus* Couper 1958, by having a more distinct reticulation in the sacci and the proximal surface of the body. The new species differs from *Lygistepollenites florinii* (Cookson & Pike) Stover & Evans 1973 by having smoothly rounded sacci outlines and by lacking looped endosexinal ridges within the sacci.

HOLOTYPE: Specimen on slide P29746, 62 x 45 μ overall.

TYPE LOCALITY AND STRATA: Willung-121 bore at 246-248 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: Upper part of *Lygistepollenites balmei* Zone into the basal part of the *Proteacidites tuberculatus* Zone, late Paleocene into early Oligocene.

Genus *Phyllocladidites* Cookson ex Couper emended
Stover & Evans 1973

Phyllocladidites mawsonii Cookson ex Couper 1953
(not illustrated)

STRATIGRAPHIC RANGE: *Nothofagidites senectus* through the *Triporopollenites bellus* Zones, Late Cretaceous (Senonian) through Miocene.

Phyllocladidites reticulosaccatus Harris 1965
(not illustrated)

1965 *Phyllocladidites reticulosaccatus* Harris, p. 86, Pl. 26, fig. 16.

STRATIGRAPHIC RANGE: *Lygistepollenites balmei* Zone, middle and late Paleocene.

Phyllocladidites verrucosus Stover & Evans 1973
(not illustrated)

1957 *Dacrydiumites mawsonii* Cookson f. *verrucosus* Cookson, p. 47, 49, Pl. 9, figs. 15, 16.

1973 *Phyllocladidites verrucosus* Stover & Evans (in press).

STRATIGRAPHIC RANGE: *Tricolporites lilliei* through *Lygistepollenites balmei* Zones, Late Cretaceous through Paleocene.

Monocolpate Pollen

Genus *Drytopollenites* Stover, n. gen.

Type Species: *Drytopollenites semilunatus* Stover, n. sp. here designated.

DIAGNOSIS: Amb broadly elliptical, outline in lateral view more or less semicircular, aperture along flat or slightly convex surface. Sulcus extends full length of pollen; exine thin, stratified, sculpturing scabrate on type species. Specimens occur singularly, in pairs, or rarely as tetrads. Monotypic, affinity uncertain, pollen somewhat similar to those of the Dioscoreaceae, Magnoliaceae and Palmae.

COMPARISON: *Drytopollenites* differs from *Cycadopites* in shape by having a broadly rounded outline in polar view in contrast to the more narrow, nearly fusiform outline of *Cycadopites*. The sulcal margins are usually irregular and gaping and the grains are more coarsely sculptured adjacent to the apertural margins than over the rest of the exine. Among specimens of *Cycadopites*, the sulcal margins arc close together or overlapping and the exine appears sculptureless.

***Drytopollenites semilunatus* Stover, n. sp.**

(Pl. 17, fig. 1, 2)

DESCRIPTION: Pollen monosulcate, broadly elliptical in polar view, outline semicircular or nearly so in lateral view. Aperture sulcate, wide, ends usually broadly rounded, margins irregular and extend to full length or almost the full length of the grains. Exine thin, about 1 μ or less, sculpturing indistinct to scabrate, coarsest adjacent to the apertural margins. Dimensions, 26 (30) 33 μ in length, 20 of more than 100 specimens measured.

HOLOTYPE: Specimen on slide P28049, 30 μ in length.

TYPE LOCALITY AND STRATA: Bass-2 well at 4308 ft, *Proteacidites asperopolis* Zone, early Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone into the lower part of the Lower *Nothofagidites asperus* Zone, early and middle Eocene.

REMARKS: Specimens vary considerably in shape according to their orientation, amount of folding and the width of the sulcus. In none of the specimens seen in polar view were the ends of the pollen narrowly rounded, and in only a few individuals were the margins of the sulcus touching or overlapping. There is also a tendency for two (rarely more than two) grains to remain attached at their antapical ends. The species is recognizable, in spite of its variable shape, by the irregular band of coarser sculpturing bordering the sulcus which does not appear to be due to a particular mode of preservation nor to partial destruction of exine by oxidation or processing.

Genus *Liliacidites* Couper 1953

***Liliacidites bainii* Stover, n. sp.**

(Pl. 16, fig. 7, 8)

1973 *Liliacidites* sp. A, Stover & Evans (in press).

DESCRIPTION: Amb elliptical, commonly modified by folding, lateral view somewhat reniform. Sulcus extends nearly the full length of the pollen, sulcal margins smooth, outline of sulcus generally of irregular width. Nexine very thin, sexine about 1.5 μ thick, tips of pilate columellae fused to form small mesh reticulum; muri and lumina largest on the proximal surface at or near mid length, become progressively smaller towards the distal surface and towards the narrow ends of the pollen. Dimensions, 39 (47) 53 μ in length; width, 27 to 36 μ , 11 specimens measured.

COMPARISON: *Liliacidites bainii* differs from *L. lanceolatus* Stover (this paper) by having a finer mesh reticulation, particularly in the medial area of the pollen, and by being larger.

HOLOTYPE: Specimen on slide P28095, 46 x 28 μ .

TYPE LOCALITY AND STRATA: Bass-2 well at 3996 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: *Proteacidites asperopolis* Zone to about midway through the Lower *Nothofagidites asperus* Zone, early Eocene into the late Eocene.

***Liliacidites lanceolatus* Stover n. sp.**

(Pl. 16, fig. 9, 10)

DESCRIPTION: Amb elliptical, ends generally narrowly rounded. Sulcus extends full length of pollen, or nearly so, margins smooth. Exine stratification distinct, sexine thicker than nexine, latter very thin, sexine about 1 μ at midlength, slightly less at ends of pollen, reticulate. Lumina and muri larger at midlength and decrease gradually in size with the lumina becoming more regular in shape towards the ends of the pollen. Columellae singular, more widely spaced and distinct at midlength; dense, smaller and rather indistinct at the ends of the pollen. At and near midlength on some specimens the muri are perforate. Dimensions, 37 (40) 44 μ in length, 22 (24) 27 μ in width, 8 specimens measured.

COMPARISON: Consult comparison for *Liliacidites bainii* Stover.

HOLOTYPE: Specimen on slide P28050, 37 x 24 μ .

TYPE LOCALITY AND STRATA: Bass-2 well at 4648 ft, *Malvacipollis diversus* Zone, early Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* through *Triporopollenites bellus* Zones, early Eocene through Miocene.

Genus *Spinizonocolpites* Muller 1968

***Spinizonocolpites prominatus* (McIntyre) Stover &**

Evans 1973

(not illustrated)

1965 *Monosulcites prominatus* McIntyre, p. 214, figs. 33, 34.

1965 *Baltisphaeridium taylori* Cookson & Eisenack, p. 137, Pl. 16, figs. 9-11.

1968 *Spinizonocolpites echinatus* Muller, p. 11, 12, Pl. 3, fig. 3.

1973 *Spinizonocolpites prominatus* (McIntyre) Stover & Evans (in press).

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone into the Lower *Nothofagidites asperus* Zone, early and middle Eocene.

Tricolpate Pollen

Genus *Beaupreaidites* Cookson 1950

***Beaupreaidites elegansiformis* Cookson 1950**

(not illustrated)

1950 *Beaupreaidites elegansiformis* Cookson, p. 168, Pl. 1, figs. 2-4.

1973 ——— Cookson, Stover & Evans (in press).

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through the *Triporopollenites bellus* Zone, early Eocene through Miocene.

REMARKS: The lectotype, designated by Potonié (1960), is located on slide P29693, 52 μ in diameter and illustrated by Cookson (1950, Pl. 1, fig. 4).

Beaupreaidites verrucosus Cookson 1950
(not illustrated)

1950 *Beaupreaidites verrucosus* Cookson, p. 169, Pl. 1, figs. 6, 7.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone into the *Proteacidites tuberculatus* Zone, early Eocene into early Oligocene.

LECTOTYPE: Specimen on slide P29669, 45 μ in diameter, and illustrated by Cookson (1950, Pl. 1, fig. 3).

TYPE LOCALITY AND STRATA: Wensleydale, Victoria, about 10 miles NW. of Anglesea, lignitic clay, Eocene, probably early Eocene, zone equivalent uncertain.

Genus **Gothanipollis** Krutzsch 1959

Gothanipollis bassensis Stover, n. sp.
(Pl. 17, figs. 13-16)

DESCRIPTION: Pollen syncolpate or syncolporate (?), amb concavely triangular, apices bluntly rounded. Exine thin, less than 1 μ , stratification indistinct; nexine extremely thin, indistinguishable in optical section; sexine psilate in apical areas and adjacent to colpi, finely granular in interapical areas. Colpi usually gaping, margins faint, straight to somewhat sinuous, suggestion of ora on some specimens at apices. Dimensions, 16 (18) 21 μ in diameter, 7 specimens measured.

COMPARISON: Of the species assigned to *Gothanipollis*, *G. bassensis* resembles most closely *G. cockfieldensis* Englehardt 1964 from the Eocene of Mississippi, U.S.A. The new species differs from the latter by having more rounded, less recurved apices, seemingly wider colpi and finer granulation in the interapical areas.

HOLOTYPE: Specimen on slide P28066, 17 μ in diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 3996 ft, Lower *Nothofagidites asperus* Zone, middle Eocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone into the lower part of the *Proteacidites tuberculatus* Zone, middle Eocene through Oligocene.

Genus **Myrtaceidites** Cookson & Pike ex Potonié 1960

COMMENTS: Pollen conformable to the form genus *Myrtaceidites* are common in the majority of Eocene and younger assemblages from the Gippsland Basin. Although easily identifiable on a generic level, at the species level it is extremely difficult to determine species consistently and reliably. The main difficulty is the comparatively simple morphology of the pollen coupled with considerable variability of the few morphologic features. These are the shape of the pollen in polar view, the presence or absence of polar islands and their size, the nature of the pores or vestibuli and the thickness of the exine and its

sculpturing which is usually indistinct. Most of the species described by Cookson & Pike (1954) cannot be maintained when a large number of specimens are available for study. Stratigraphically, forms of *Myrtaceidites* occur initially in the *Lygistepollenites balmei* Zone, increase in abundance and diversity in Eocene zones and continue to range through the Miocene. Two species of stratigraphic significance are dealt with below.

Myrtaceidites tenuis Harris 1965
(not illustrated)

1965 *Myrtaceidites tenuis* Harris, p. 90, Pl. 27, figs. 30, 31.

1973 ——— Harris, Stover & Evans (in press).

STRATIGRAPHIC RANGE: Within the *Malvacipollis diversus* Zone through the *Proteacidites asperopolus* Zone, early Eocene.

Myrtaceidites verrucosus Partridge, n. sp.
(Pl. 17, fig. 17-19)

DESCRIPTION: Pollen subisopolar, amb triangular, sides slightly convex. Apertures colporate, ends of colpi extend to about midway between the poles and equator or beyond to outline polar islands, polar arcs or islands 4 to 10 μ in diameter, vestibuli variably developed, always present. Exine 0.5 to 2 μ thick, nexine thinner than sexine, latter granulate or verrucate, size of sculpturing proportional to the size of the pollen, on large specimens verrucae are larger equatorially (up to 3 μ long) and on small specimens the sculpturing is more distinct at the poles. Dimensions, equatorial diameter 12 (18) 26 μ , 18 specimens measured.

COMPARISON: *Myrtaceidites verrucosus* differs from other species of *Myrtaceidites* by having a distinctively sculptured exine.

HOLOTYPE: Specimen on slide P29743, 25 μ in diameter.

TYPE LOCALITY AND STRATA: Yallourn Open Cut, Victoria, clay at floor of the cut, *Triporopollenites bellus* Zone, late Miocene.

STRATIGRAPHIC RANGE: *Proteacidites asperopolus* Zone through *Triporopollenites bellus* Zone, early Eocene through Miocene.

Genus **Tricolpites** Cookson ex Couper 1953

Type Species: **Tricolpites reticulatus** Cookson 1947, designated by Couper (1953, p. 61)

REMARK: The form genus *Tricolpites* is used following Couper (1953) for tricolpate grains with variable exine sculpture.

Tricolpites confessus Stover, n. sp.
(Pl. 17, fig. 3)

1973 *Tricolpites* sp. A, Stover & Evans (in press).

DESCRIPTION: Pollen isopolar, amb circular. Triaperturate, colpi 8 to 12 μ long, rather deeply incised, commonly open, with the suggestion of an inner membrane (nexine?) across the colpi on some

specimens, apocolpia about 3 to 4 μ in diameter. Exine approximately 1.5 μ thick, not clearly differentiated, surface psilate with slight irregularities when viewed in phase contrast. Dimensions, equatorial diameter 19 (21) 25 μ , 16 specimens measured.

COMPARISON: In size and shape, *Tricolpites confessus* is similar to *T. pannosus* Dettmann & Playford 1968 but differs by having more deeply incised colpi, a slightly thicker exine and a psilate surface.

HOLOTYPE: Specimen on slide P28097, 22 μ in diameter.

TYPE LOCALITY AND STRATA: Tuna-1 well at 5927 ft, *Tricolpites longus* Zone, early Paleocene, possibly middle Paleocene.

STRATIGRAPHIC RANGE: *Tricolporites lilliei* and *Tricolpites longus* Zones, Late Cretaceous to early Paleocene, possibly middle Paleocene.

***Tricolpites gillii* Cookson 1957**
(not illustrated)

1957 *Tricolpites gillii* Cookson, p. 49, Pl. 10, figs. 12-15.

1965 ——— Cookson, Harris, p. 88, Pl. 27, fig. 13.

1968 ——— Cookson, Dettmann & Playford, p. 84, Pl. 8, fig. 14.

1969 ——— Cookson, Dettman & Playford, p. 13, fig. 19.

1973 ——— Cookson, Stover & Evans (in press).

STRATIGRAPHIC RANGE: *Nothofagidites senectus* Zone into the lower part of the *Malvacipollis diversus* Zone, Late Cretaceous (Senonian) into early Eocene.

***Tricolpites incisus* Stover, n. sp.**
(Pl. 17, fig. 4, 5)

DESCRIPTION: Pollen isopolar, amb circular, oblate in equatorial view. Exine stratification fairly distinct, nexine about 0.5 μ or less in thickness, sexine about 1 μ thick, reticulate. Lumina of reticulum irregularly polygonal, 1 to 2 μ in diameter, generally smaller in polar than in equatorial areas; muri less than 1 μ in width, commonly perforate, perforations about 0.5 μ in diameter and usually more numerous in the equatorial areas. Colpi long, straight, margins smooth, apocolpia small. Dimensions, equatorial diameter variable depending upon amount of compression, varies between 21 and 33 μ , average polar diameter about 25 μ , 13 specimens measured.

COMPARISON: *Tricolpites incisus* differs from other tricolpate reticulate pollen by having perforate muri over a major portion of the pollen.

HOLOTYPE: Specimen on slide P28049, 31 μ in diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 4308 ft *Proteacidites asperopolus* Zone, early Eocene.

STRATIGRAPHIC RANGE: Upper part of *Malvacipollis diversus* Zone into Lower *Nothofagidites asperus* Zone, early Eocene to late Eocene.

***Tricolpites longus* Stover & Evans 1973**
(not illustrated)

1973 *Tricolpites longus* Stover & Evans (in press).

STRATIGRAPHIC RANGE: Upper part of *Tricolporites lilliei* Zone through *Tricolpites longus* Zone, Late Cretaceous through early Paleocene, possibly middle Paleocene.

***Tricolpites phillipsii* Stover, n. sp.**
(Pl. 17, fig. 6, 7)

1973 *Tricolpites* sp. B, Stover & Evans (in press).

DESCRIPTION: Pollen isopolar, amb convexly triangular, oblate in polar view. Exine about 1 μ thick, slightly thicker along apertures on some specimens, indistinctly differentiated, nexine appears thinner than sexine but not appreciably so. Exine shallowly incised by narrow, meandroid grooves surrounding irregularly shaped islands of sexine. Colpi short, commonly with uneven margins, and on some specimens the margins are smooth and thickened. Dimensions, equatorial diameter 25 (30) 36 μ , 12 specimens measured.

COMPARISON: *Tricolpites phillipsii* differs from *T. gillii* Cookson 1957 by having a distinctly sculptured exine, and convex rather than slightly concave sides.

HOLOTYPE: Specimen on slide P28066, 30 μ in diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 3996 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: *Lygistipollenites balnei* Zone through the Lower *Nothofagidites asperus* Zone, middle Paleocene into late Eocene.

***Tricolpites sabulosus* Dettmann & Playford 1968**
(not illustrated)

1968 *Tricolpites sabulosus* Dettmann & Playford, p. 85, Pl. 8, figs. 11-31.

STRATIGRAPHIC RANGE: *Nothofagidites senectus* Zone into the *Tricolporites lilliei* Zone, Late Cretaceous.

***Tricolpites simatus* Partridge, n. sp.**
(Pl. 17, figs. 8-11)

DESCRIPTION: Pollen isopolar, amb triangular with straight to concave sides and truncated or broadly rounded apices. Colpi 3 to 10 μ long (average length 6 μ), commonly with faint arc-like poleward extensions. Exine vaguely to moderately well differentiated, columellae not discernible, exine from less than 1 μ to 2 μ thick, finely perforate interapically, nexine equal to or greater than sexine in thickness. Polar areas with triangular to subcircular psilate thickenings whose outlines parallel that of the equatorial margin, sides of polar thickenings generally faintly striate. Dimensions, 17 (22) 26 μ in diameter, 38 specimens measured.

COMPARISON: The triangular to subcircular polar thickenings are diagnostic of the species which differs from *Tricolpites thomasi* Cookson & Pike 1954 by lacking interrational reticulation.

HOLOTYPE: Specimen on slide P29755, 24 μ in diameter.

TYPE LOCALITY: Willung-121 bore at 324-326 ft, Lower *Nothofagidites asperus* Zone, middle Eocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone, middle into late Eocene.

Tricolpites thomasi Cookson & Pike 1954

(Pl. 17, fig. 12)

1954 *Tricolpites thomasi* Cookson & Pike, p. 214, Pl. 2, figs. 92-94.

LECTOTYPE: Specimen on slide P29660, and illustrated by Cookson & Pike (1954, Pl. 2, fig. 92).

TYPE LOCALITY AND STRATA: Birregurra-1 well at 842-843 ft, Eocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone, middle Eocene into the lower part of the late Eocene.

Tricolporate Pollen

Genus **Anisotricolporites** Partridge, n. gen.

Type species: **Anisotricolporites triplaxis** Partridge, n. sp. here designated.

DIAGNOSIS: Pollen free, anisopolar, triaperturate, apertures equatorial, pores in nexine circular and simple; colpi in sexine developed on one polar surface only. Surface of sexine granulate on type species. Monotypic, affinity unknown.

COMPARISON: The development of colpi on just one polar surface distinguishes this form from other tricolporate form genera.

Anisotricolporites triplaxis Partridge, n. sp.

(Pl. 18, fig. 8, 9)

DESCRIPTION: Amb convexly triangular; anisopolar, polar surface with colpi (distal surface?) more convex than opposite surface. Apertures equatorial, tricolporate; pores circular, 2 to 3 μ in diameter; colpi on one hemisphere only, colpi as wide as pores at the equator, narrow gradually toward the pole, apocolpia small. Exine 1 to 1.5 μ , sexine and nexine clearly differentiated only adjacent to the apertures, approximately equally thick, columellae not discernible; surface of exine densely granulate. Dimensions, equatorial diameter 17 (19) 22 μ , 17 specimens measured; polar diameter 18 to 19 μ , 4 specimens.

HOLOTYPE: Specimen on slide P29728, 18 μ in diameter.

TYPE LOCALITY AND STRATA: Willung-121 bore at 324-326 ft, Lower *Nothofagidites asperus* Zone, middle Eocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone, middle Eocene and into lower part of late Eocene.

Genus **Bombacacidites** Couper 1960

Bombacacidites bombaxoides Couper 1960

(Pl. 19, fig. 3)

1960 *Bombacacidites bombaxoides* Couper, p. 53, Pl. 7, figs. 13, 14.

REMARKS: The holotype and paratype of this species were examined by P. R. Evans who concurred with

the assignment of the Gippsland Basin specimens to *Bombacacidites bombaxoides*. The nexine is very thin (less than 0.5 μ) except at the apertures, where it is about 1 μ thick and where it forms a margo 1 to 2 μ wide around each colpus. The reticulate sexine and the gradual decrease in the size of the lumina from the polar to the equatorial areas, particularly in the apical regions, are evident on the three Australian specimens. STRATIGRAPHIC RANGE: *Proteacidites asperopolus* Zone, early Eocene.

Genus **Concolpites** Partridge, n. gen.

Type species: **Concolpites leptos** Partridge, n. sp. here designated.

DIAGNOSIS: Parasyncolpate, isopolar pollen, tricolpate pollen with large atria underlying much of the colpi, amb concavely triangular. Exine stratified, sexine thicker than nexine, latter absent in apertural equatorial areas. Monotypic, affinity unknown.

COMPARISON: *Concolpites* differs from *Cupanieidites* Cookson & Pike 1954 by having large, conspicuous atria and a convexly triangular amb. In addition, the type species of *Concolpites* is significantly smaller than species of *Cupanieidites*.

Concolpites leptos Partridge, n. sp.

(Pl. 18, figs. 1, 2)

DESCRIPTION: Amb convexly triangular, pollen parasyncolpate, polar islands 4 to 6 μ in width. Colpi distinct, atria large, 5 to 6 μ deep, outline in polar view broadly concave or chevron-like, limit of nexine at base of atria whose deepest points also coincide with the positions where the colpi bifurcate to form the polar islands. Exine less than 1 μ thick, nexine extremely thin, sexine very finely reticulate to punctoreticulate in interradial areas. Dimensions, 12 (16) 19 μ in diameter, 14 specimens measured.

HOLOTYPE: Specimen on slide P29756, 19 μ in diameter.

TYPE LOCALITY AND STRATA: Alberton West-138 bore at 188 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: *Proteacidites asperopolus* Zone into basal part of *Proteacidites tuberculatus* Zone, early Eocene to early Oligocene.

Genus **Cupanieidites** Cookson & Pike 1954

1954 *Cupanieidites* Cookson & Pike, p. 210.

1959 *Duplopollis* Krutzsch, p. 144.

1959 *Cupanieidites* Cookson & Pike, emended Krutzsch, p. 144.

1960 ——— Cookson & Pike, Potonié, p. 106.

1965 *Duplopollis* Krutzsch, Harris, p. 89.

1965 *Cupanieidites* Cookson & Pike, Belskey, Boltenhagen & Potonié, p. 77.

1967 ——— Cookson & Pike, Boltenhagen, p. 348.

Type Species: **Cupanieidites major** Cookson & Pike 1954, designated by Krutzsch (1959, p. 144).

COMMENTS: In 1959 Krutzsch proposed *Duplopollis* for the reception of his new species, *D. myrtoideis*, and

for *D. orthoteichus*—a form previously assigned to *Cupanieidites* by Cookson and Pike (1954). Krutzsch made no definitive distinction between *Duplopollis* and *Cupanieidites*, and stated only that in the former the polar islands are always clearly separated, whereas in the latter they are absent or their presence can be only intimated. Belsky, Boltenhagen and Potonié (1965) found Krutzsch's hazy criterion for separating the two genera untenable and were compelled, therefore, to reject *Duplopollis* and to maintain *Cupanieidites* essentially in its original concept. Specimens from the Gippsland Basin substantiate their observations; the desirability of retaining *Cupanieidites* is further supported by the data presented by Cookson and Pike (1954, p. 211, table 2) in which they show the development of the polar islands is variable among pollen from extant species as well as from fossil material.

Cupanieidites major/orthoteichus
(not illustrated)

STRATIGRAPHIC RANGE: *Malvacipollis diversus* through the *Triporopollenites bellus* Zones, early Eocene through Miocene.

REMARKS: Because specimens of *Cupanieidites* spp. occur fairly commonly and consistently in Eocene and younger spore-pollen assemblages from the Gippsland Basin, a fairly large collection of individuals has been recorded. Based on these specimens, separation of *C. major* and *C. orthoteichus* cannot be maintained owing to variability in the size and shape of the pollen in polar view, in the thickness of the exine and the clarity of the exine stratification, in the size and outline of the polar islands as well as their presence or absence, in the size of the sexine reticulation and finally in the prominence and dimensions of the ora. The majority of the specimens conform more closely to the description of *C. orthoteichus* than to that of *C. major*, but no combination of morphologic characters was found that could be used for identifying the two species consistently and confidently.

Until the specimens of *C. major* illustrated by Cookson and Pike (1954) are located and compared with those of *C. orthoteichus*, we prefer to treat the two forms as one species.

Genus *Gemmatricolporites* Leideimyer 1966
***Gemmatricolporites gestus* Partridge, n. sp.**
(Pl. 19, fig. 4)

DESCRIPTION: Amb subcircular, outline commonly distorted; oblate to subspherical; tricolporate, pores indistinct, circular, colpi relatively short. Exine exclusive of sculpturing 1.5 to 3 μ thick, nexine equal to or slightly thicker than sexine, columellate layer not discernible. Surface of sexine granulate, gemmate and/or verrucate; granulae 0.5 μ diameter, gemmae and verrucae up to 11 μ in diameter, average size range 3 to 6 μ , height up to 5 μ . Dimensions, 38 (45) 55 μ in diameter, 11 specimens measured.

COMPARISONS *Gemmatricolporites gestus* differs from *G. divaricatus* Leideimyer 1966 and *G. berbicensis* Leideimyer 1966 by having more widely spaced, more irregular sculpturing and by being larger.

HOLOTYPE: Specimen on slide P29855, 55 μ in diameter.

TYPE LOCALITY AND STRATA: Rosedale-1 well at 2287-2289 ft, Lower *Nothofagidites asperus* Zone, middle Eocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone, middle and late Eocene.

Genus *Intratropollenites* (Thomson & Pflug)
emended May 1961

***Intratropollenites notabilis* (Harris) Stover,**
n. comb.
(not illustrated)

1965 *Tiliaepollenites notabilis* Harris, p. 91, Pl. 28, figs. 2, 3.

1973 *Tiliaepollenites notabilis* Harris, Stover & Evans (in press).

REMARKS: According to Mai (1961) *Tiliaepollenites* is invalid as a form generic name because the type species is based on pollen from an extant species of *Tilia*, consequently specimens previously attributed to *Tiliaepollenites notabilis* by Harris (1965) and by Stover & Evans (in press) are now identified as *Intratropollenites notabilis* (Harris) Stover, n. comb. Supplemental morphological data based on observations made on several exceptionally well preserved species are given below.

The exine consists of a thin nexine (less than 0.5 μ) that thickens appreciably around the apertures and a distinctively sculptured sexine about 1.5 μ thick. A fairly homogeneous columellate layer composed of evenly distributed, low, uniform columellae overlies the nexine and is in turn overlain by a reticulate ectosexine. Almost without exception the muri of the reticulum are narrower than the lumina and are essentially uniform in width. The lumina, in contrast, average slightly over 1 μ across in the polar areas and increase gradually to about 2.5 μ in the interapertural areas. Occasional, widely scattered punctae occur at the intersections of muri on some specimens.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* and *Proteacidites asperopolus* Zones, early Eocene.

Genus *Ilexpollenites* Thiergart ex Potonié 1960
***Ilexpollenites anguloclavatus* McIntyre 1968**
(not illustrated)

1968 *Ilexpollenites anguloclavatus* McIntyre, p. 183, figs. 12, 13.

REMARKS: Specimens of *Ilexpollenites anguloclavatus* occur throughout a major portion of the Gippsland Basin Tertiary section. The size, shape and density of the sculpturing as well as the clarity of the apertures are highly variable. Because of variability and the occurrence of intergradational types, it was not possible to separate species consistently or to refer the Gippsland Basin specimens confidently to previously published species. We have, therefore, chosen to place the Australian specimens in *I. anguloclavatus* and to allow greater variability than is indicated in the original description.

STRATIGRAPHIC RANGE: Within the *Tricolpites longus* Zone to about midway through the *Proteacidites tuberculatus* Zone, middle Paleocene into the early Miocene.

**Genus *Santalumidites* Cookson & Pike emended
Partridge**

1954 *Santalumidites* Cookson & Pike, p. 209.

1960 ——— Cookson & Pike, emended Potonié, p. 123.

Type Species: *Santalumidites cainozoicus* Cookson & Pike 1954, monotypic when proposed.

DIAGNOSIS (Emended): Pollen isopolar, prolate, triporate or tricolporate, pores distinct, colpi short. Sexine present in wide equatorial band, absent in polar areas and thickened equatorially, columellae faint, dense, sexine scabrate or psilate.

COMPARISON: *Santalumidites* differs from *Florschuetzia* Germeraad et al 1968 by having porate and colporate apertures and by lacking sexine in the polar area.

***Santalumidites cainozoicus* Cookson & Pike 1954
(not illustrated)**

1954 *Santalumidites cainozoicus* Cookson & Pike, p. 209, Pl. 2, figs. 67-70, not fig. 71.

1960 ——— Cookson & Pike, Potonié, p. 123, Pl. 7, fig. 161.

LECTOTYPE: Potonié (1960) designated the specimen illustrated by Cookson and Pike (1954, Pl. 2, fig. 67) as lectotype, which is located on slide P29677.

STRATIGRAPHIC RANGE: Within *Malvacipollis diversus* Zone through the Lower *Nothofagidites asperus* Zone, early Eocene into late Eocene.

REMARKS: Dimensions of 25 Gippsland Basin specimens of *Santalumidites cainozoicus* are: Polar diameter 24 (36) 60 μ , equatorial diameter 15 (22) 43 μ .

Genus *Schizocolpus* Stover, n. gen.

Type Species: *Schizocolpus marlinensis*, Stover, n. sp. here designated.

DIAGNOSIS: Pollen isopolar, oblate, amb roundly triangular, operculate. Apertures tricolporate, each colpus diorate, ora at or near the ends of the colpi. Opercula composed of sexinous material, sexine puncto-reticulate to reticulate on known species, monotypic.

COMPARISON: *Schizocolpus* differs from *Psilatricolporites* (van der Hammen) ex van der Hammen & Wymstra (1964) by having diorate apertures and a distinctly sculptured sexine.

AFFINITY: Possibly Didymelaceae; see drawing of *Didymeles madagascariensis* in Erdtman (1952).

***Schizocolpus marlinensis* Stover n. sp.
(Pl. 18, figs. 3, 4)**

1973 *Tricolporites* sp. A, Stover & Evans (in press).

DESCRIPTION: Pollen isopolar, oblate, amb roundly triangular. Nexine extremely thin (less than 0.5 μ),

smooth, exine about 1 μ thick, puncto-reticulate to finely reticulate, lumina or punctae circular or nearly so, less than 1 μ in diameter, muri also less than 1 μ in diameter. On some specimens the diameter of the lumina tends to be slightly more than the width of the muri. Columellae not discernible. Colpi long, apocolpia 5 to 8 μ , colpi covered by narrow, elongate opercula; diorate, ora at or near the ends of the colpi, circular or nearly so, 1.5 to 2.5 μ in diameter, nexine at margin of ora very slightly thickened. Dimensions, equatorial diameter, 21 (24) 29 μ , 14 specimens measured.

COMPARISON: The diorate condition of the colpate apertures makes this form unique among fossil pollen.

HOLOTYPE: Specimen on slide P28079, 23 μ in diameter.

TYPE LOCALITY AND STRATA: Marlin-1 well at 4891-92 ft, *Malvacipollis diversus* Zone, early Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone into the Lower *Nothofagidites asperus* Zone, early and middle Eocene.

**Genus *Symplocoipollenites* Potonié 1960
Symplocoipollenites austellus Partridge, n. sp.
(Pl. 17, fig. 20)**

DESCRIPTION: Pollen isopolar, amb triangular, sides straight to convex, outline in equatorial view broadly elliptical. Exine up to 1.5 μ thick interradially, nexine about twice as thick as sexine and even thicker behind vestibula. Sexine granulate, granulae less than 0.5 μ in diameter, columellae not discernible. Colpi short, vestibula 6 to 8 μ wide, 2 to 3 μ deep in polar view. Dimensions, 20 (24) 29 μ in diameter, 13 specimens measured.

COMPARISON: The new species differs from *Symplocoipollenites vestibulum* Potonié 1960 by being smaller and by having shorter colpi.

HOLOTYPE: Specimen on slide P29798, 28 μ in diameter.

TYPE LOCALITY AND STRATA: Wurruk-1 well at 426 ft, *Triporopollenites bellus* Zone, late Miocene.

STRATIGRAPHIC RANGE: *Triporopollenites bellus* Zone, late Miocene.

Genus *Tricolporites* Cookson 1947

Type Species: *Tricolporites sphaerica* Cookson 1947, p. 195, Pl. 9, figs. 14, 15, text-fig. 4, monotypic when proposed.

DIAGNOSIS (Emended): Pollen free, isopolar, radially symmetrical, tricolporate. Exine variable in thickness and sculpturing. Size variable.

REMARKS: The diagnosis for *Tricolporites* is intentionally broad to accommodate the Australian species described under this name by Cookson (1947), Harris (1965) and those species described herein. This usage incorporates a number of form genera erected subsequently to *Tricolporites* of which many are defined more explicitly on ornament type. A critical appraisal of these genera is beyond the scope of this work.

***Tricolporites sphaerica* Cookson 1947**

(Pl. 18, figs. 5-7)

1947 *Tricolporites sphaerica* Cookson, p. 195, Pl. 9, figs. 14, 15, text-fig. 4.

DESCRIPTION (Revised): Pollen isopolar, suboblate to prolate, amb subtriangular with broadly rounded, incurved apices. Colpi long, indistinct at polar extremities, ora lalongate, 3 to 3.5 μ high, about 6 to 8 μ wide, lateral margins usually obscured by overlying reticulations. Exine 1 to 1.5 μ thick equatorially, up to 3.5 μ thick at the poles, nexine 0.5 to 1.5 μ thick, thicker than sexine with both layers thickest at the poles. Columellae faint but distinct, of uniform height, single, underlie muri of reticulum. Lumina circular to polygonal, 0.5 to 1.5 μ in diameter, mesh commonly smallest around the equator where sexine is thinnest, muri less than 1 μ in width. Dimensions, polar diameter, 20 (26) 31 μ , equatorial diameter 17 (24) 29 μ , 11 specimens measured.

NEOTYPE: Specimen on slide P29875, 29 x 31 μ , selected from topotype material.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone to the *Triporepollenites bellus* Zone, late Eocene through Miocene.

REMARKS: The revised description is based on specimens from topotype material. Although specimens are sparse, there is little likelihood of confusion with other tricolporate species in the assemblages because the only other similar appearing form is an undescribed species with a morphology quite distinct from that of *Tricolporites sphaerica*. There is considerable variability in the shape, the size of the mesh of the reticulum and in the amount of differential thickening of the exine among specimens of *T. sphaerica*. Some specimens are very similar to *T. microreticulatus* Harris 1965 and further study may prove they are conspecific.

***Tricolporites angurium* Partridge, n. sp.**

(Pl. 18, fig. 10)

DESCRIPTION: Pollen isopolar, prolate to subprolate, amb circular. Colpi long, acolpia small, ora generally indistinct, 8 to 10 μ long, equatorial dimension not determined. Exine 1 to 2.5 μ thick, nexine and sexine generally equal in thickness, but either layer may be slightly thicker than the other. Exine thickness constant between poles and equator in equatorial view, becomes less toward apertures in polar view. Sexine reticulate, muri underlain usually by single columellae, lumina less than 0.5 to 1 μ in diameter and of fairly uniform size. Dimensions, polar diameter 34 (39) 46 μ ; equatorial diameter 24 (30) 38 μ , 50 specimens measured.

COMPARISON: *Tricolporites angurium* differs from other Australian species of *Tricolporites* by having a delicate, fine-mesh reticulum, long colpi with indistinct ora and a broadly elliptical outline.

HOLOTYPE: Specimen on slide P29845, 41 x 29 μ .

TYPE LOCALITY AND STRATA: Wurruk-1 bore at 3023 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone, middle into late Eocene.

REMARKS: The description is based on a large number of specimens from the type locality. An occasional specimen has double rather than single columellae and some have a slightly thicker exine with a coarser reticulation.

***Tricolporites leuros* Partridge, n. sp.**

(Pl. 19, figs. 5-7)

DESCRIPTION: Pollen isopolar, oblate, poles and equatorial areas tend to be flattened thereby giving the pollen a polygonal outline in equatorial view, amb subcircular. Colpi long, ends bluntly rounded to pointed, ora indistinct, circular, up to 3 μ in diameter. Exine 2 to 4 μ thick in interradial regions, nexine 1.5 to 3 μ thick, both layers become thinner toward the apertures and the sexine is absent in a band about 1.5 μ wide adjacent to the colpi. Sexine psilate, columellae barely discernible. Dimensions, equatorial diameter 20 (26) 40 μ , polar diameter 19 to 23 μ , 21 specimens measured.

COMPARISON: *Tricolporites leuros* differs from *T. valvatus* Harris 1972 by being smaller and by the absence of the sexine adjacent to the colpi.

HOLOTYPE: Specimen on slide P29721, 22 μ in diameter.

TYPE LOCALITY AND STRATA: Childers Formation at Moolamoon Coal Mine, top coal seam, *Proteacidites tuberculatus* Zone, early Oligocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone through the *Triporepollenites bellus* Zone, middle Eocene through Miocene.

***Tricolporites lilliei* (Couper) Stover & Evans 1973**

(not illustrated)

1953 *Tricolpites lilliei* Couper, p. 62, Pl. 8, figs. 116, 117.

1960 ——— Couper, Couper, p. 64, Pl. 10, fig. 19.

1973 *Tricolporites lilliei* (Couper) Stover & Evans (in press).

STRATIGRAPHIC RANGE: *Tricolporites lilliei* and *Tricolpites longus* Zones, Late Cretaceous to early Paleocene, possibly middle Paleocene.

***Tricolporites paenestriatus* Stover, n. sp.**

(Pl. 19, fig. 1)

DESCRIPTION: Pollen isopolar, prolate, amb circular. Exine stratification vague to distinct, nexine thin, about 0.5 μ ; sexine from 1 μ to slightly more than 1 μ thick, finely rugulate and appearing somewhat striate on some specimens, columellae small, evenly distributed, commonly faint. Apertures colpate or colporate, generally the latter, colpi extend about 3/4 the length of pollen, ora small, lalongate, usually discernible. Dimensions, polar diameter 23 (27) 37 μ ; equatorial diameter 14 (19) 28 μ , 21 specimens measured.

COMPARISON: *Tricolporites paenestriatus* differs from *T. angurium* Partridge (this paper) by being smaller

and by having the ridges of the sexine aligned to form a rugulate to striate pattern.

HOLOTYPE: Specimen on slide P28050, 31 μ in polar diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 4648 ft, *Malvacipollis diversus* Zone, early Eocene.

STRATIGRAPHIC RANGE: Within the *Lygistepollenites balmei* Zone through the Lower *Nothofagidites asperus* Zone, early Eocene into late Eocene.

Tricolporites retequetrus Partridge, n. sp.
(Pl. 19, figs. 8, 9)

DESCRIPTION: Pollen free or retained in tetrads, free pollen weakly anisopolar, oblate to prolate, amb convexly triangular. Apertures interrational, colpi short to moderately long, apocolpia generally large, pores small and indistinct. Exine psilate at poles, 1.5 to 3 μ thick at apices and becomes thinner towards the apertures. Nexine 0.5 to 2.5 μ thick at the poles, thickest equatorially, sexine thicker than, also thickest equatorially and coarsely reticulate between apertures with large polygonal to labyrinthine lumina and wide muri (2 to 3 μ). Columellae distinct, about 0.5 μ in diameter at the poles, over 1 μ in the apical areas, closely and fairly evenly spaced. Dimension, equatorial diameter 26 (41) 55 μ , polar diameter 20 to 41 μ , 10 individual specimens measured.

COMPARISON: The psilate polar surfaces and coarsely reticulate equatorial areas are diagnostic of *Tricolporites retequetrus* and serve to separate it from other Australian species of *Tricolporites*.

HOLOTYPE: Tetrad on slide P29770, overall diameter 62 μ , individual pollen 34 x 40 μ .

TYPE LOCALITY AND STRATA: Wurruk-1 well at 2898 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: Within the Lower *Nothofagidites asperus* Zone through the *Proteacidites tuberculatus* Zone, late Eocene to early Miocene.

Tricolporites scabratus Harris 1965
(Pl. 19, fig. 2)

1965 *Tricolporites scabratus* Harris, p. 97, Pl. 27, fig. 17.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through the Lower *Nothofagidites asperus* Zone, early Eocene into late Eocene.

Genus **Tubulifloridites** Cookson 1947
Tubulifloridites antipodica Cookson 1947
(Pl. 18, figs. 11, 12)

1947 *Tricolpites* (*Tubulifloridites*) *antipodica* Cookson, p. 138, Pl. 15, fig. 44.

1960 *Tubulifloridites antipodica* Cookson, Potonié, p. 106, Pl. 6, fig. 124.

STRATIGRAPHIC RANGE: *Triplopollenites bellus* Zone, late Miocene.

Polycolpate Pollen

Genus *Nothofagidites* Potonié 1960

COMMENTS: Australian species of *Nothofagidites* are discussed by Cookson (1946, 1959) and by Stover and Evans (1972). These pollen are particularly abundant in middle Eocene and younger assemblages from the Gippsland Basin; however, most of the species have relatively long ranges. Species identified from the Gippsland Basin and their ranges are given below.

Nothofagidites asperus (Cookson) Stover & Evans 1973.

Lower *Nothofagidites asperus* through the *Triplopollenites bellus* Zone, middle Eocene through Miocene.

Nothofagidites brachyspinulosus (Cookson) Harris 1965.

Lygistepollenites balmei Zone through the *Triplopollenites bellus* Zone, middle Paleocene through Miocene.

Nothofagidites deminutus (Cookson) Stover & Evans 1973.

Within upper part of *Malvacipollis diversus* Zone through the *Triplopollenites bellus* Zone, early Eocene through Miocene.

Nothofagidites emarcidus (Cookson) Harris 1965
Malvacipollis diversus through the *Triplopollenites bellus* Zone early Eocene through Miocene.

Nothofagidites endurus Stover & Evans 1973
Tricolporites lilliei Zone into the *Malvacipollis diversus* Zone, Late Cretaceous into early Eocene.

Nothofagidites falcatus (Cookson) Stover & Evans 1973.

Lower *Nothofagidites asperus* Zone through the *Triplopollenites bellus* Zone, middle Eocene through Miocene.

Nothofagidites flemingii (Couper) Potonié 1960.
Lygistepollenites balmei Zone into the *Proteacidites tuberculatus* Zone, late Paleocene through Oligocene.

Nothofagidites goniatus (Cookson) Stover & Evans 1973.

Within upper part of *Malvacipollis diversus* Zone into the *Proteacidites tuberculatus* Zone, early Eocene through Oligocene.

Nothofagidites heterus (Cookson) Stover & Evans 1973.

Within upper part of *Malvacipollis diversus* Zone through the *Triplopollenites bellus* Zone, early Eocene through Miocene.

Nothofagidites senectus Dettmann & Playford 1968.
Nothofagidites senectus Zone into the *Tricolpites longus* Zone, Late Cretaceous (Senonian) to early Paleocene.

Nothofagidites vansteenisi (Cookson) Stover & Evans 1973.

Lower *Nothofagidites asperus* Zone through the *Tripopollenites bellus* Zone, middle Eocene through Miocene.

Genus **Polycolpites** Couper 1953
Polycolpites esobalteus McIntyre 1968
 (Pl. 20, figs. 10, 11)

1968 *Polycolpites esobalteus* McIntyre, p. 197, figs. 67-69.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through *Tripopollenites bellus* Zone, early Eocene through Miocene.

Polycolpites langstonii Stover, n. sp.
 (Pl. 20, fig. 12)

DESCRIPTION: Stephanocolpate, subspherical, amb circular; exine stratification indistinct, nexine extremely thin (less than $0.5\ \mu$), occasionally separated from sexine and appearing as a wrinkled, internal membrane. Sexine about $3\ \mu$ thick, homogeneous, psilate, without columellae. Colpi long, unmodified, number 6 to 8, commonly 7. Dimensions, 50 (54) $63\ \mu$, measured on 11 randomly oriented specimens.

COMPARISON: *Polycolpites langstonii* differs from *P. esobalteus* McIntyre 1968 by being considerably larger, and by having a thicker exine and fewer colpi.

HOLOTYPE: Specimen on slide P28055, $52\ \mu$ in diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 4937 ft, *Lygistepollenites balmei* Zone, late Paleocene.

STRATIGRAPHIC RANGE: *Lygistepollenites balmei* Zone, middle to late Paleocene.

Polycolpites reticulatus Couper 1960
 (Pl. 20, fig. 7)

1960 *Polycolpites reticulatus* Couper, p. 63, Pl. 10, figs. 6, 7.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone through the *Tripopollenites bellus* Zone, late Eocene through Miocene.

Genus **Psilastephanocolporites** Leidelmeyer 1966
Psilastephanocolporites micus Partridge, n. sp.
 (Pl. 20, figs. 3-6)

DESCRIPTION: Pollen isopolar, oblate, amb circular to slightly polygonal, stephanocolporate. Apertures 6 to 8, usually 7, colpi short, indistinct, ora distinct, circular, $2.5\ \mu$ in diameter. Exine less than $1\ \mu$ thick, nexine very thin, loosely attached to indistinct, rather widely spaced columellae. Tectum perforate, scabrate or rarely with low indistinct granulae. Dimensions, equatorial diameter 16 (24) $30\ \mu$, 12 specimens measured.

COMPARISON: No similar appearing pollen known from the Tertiary of southeastern Australia.

HOLOTYPE: Specimen on slide P29851, $25\ \mu$ in diameter.

TYPE LOCALITY AND STRATA: Yallourn Open Cut, Victoria, Yallourn Seam along north wall of cut, 80 ft above base of the seam, *Tripopollenites bellus* Zone, late Miocene.

STRATIGRAPHIC RANGE: Upper part of *Proteacidites tuberculatus* Zone through the *Tripopollenites bellus* Zone, early and late Miocene.

Tetracolporate Pollen

Genus **Sapotaceoidapollenites** Pontonié, Thomson & Thiergart 1950

Sapotaceoidapollenites rotundus Harris 1972
 (Pl. 20, fig. 13)

1972 *Sapotaceoidapollenites rotundus* Harris, p. 56, figs. 17, 18

STRATIGRAPHIC RANGE: *Proteacidites asperopolus* Zone through the *Tripopollenites bellus* Zone, early Eocene through Miocene.

Genus **Tetracolporites** Couper 1953
Tetracolporites verrucosus Stover, n. sp.
 (Pl. 20, figs. 1, 2)

1973 *Tetracolporites* sp. A, Stover & Evans (in press).

DESCRIPTION: Pollen isopolar, amb circular to sub-quadrangular, outline ellipsoidal in equatorial view, slightly longer than wide. Exine stratification indistinct, nexine very thin, not discernible in some specimens, sexine clavate, clavae about $1\ \mu$ high, 1 to $2.5\ \mu$ in diameter, closely spaced so as to give the appearance of a negative reticulum in plan view. Apertures colporate, colpi extend about $3/4$ length of pollen, bordered by narrow margins on some specimens, ora circular to slightly elongate, commonly obscure and observed most commonly on damaged specimens. Dimensions, length 31 (35) $39\ \mu$, width 23 (27) $37\ \mu$, 11 specimens measured.

COMPARISON: *Tetracolporites verrucosus* differs from *T. oamaruensis* Couper 1953 by being verrucate and by having a circular rather than a rectangular amb and a thinner exine.

HOLOTYPE: Specimen on slide P28082, equatorial diameter $28\ \mu$.

TYPE LOCALITY AND STRATA: Marlin-2 well at 8121 ft, Latrobe Group, *Lygistepollenites balmei* Zone, late Paleocene.

STRATIGRAPHIC RANGE: *Tricolpites longus* Zone into the *Lygistepollenites balmei* Zone, early and middle Paleocene, possibly into the late Paleocene.

Monoporate Pollen

Genus **Aglaoreidia** Erdtman 1960
Aglaoreidia qualumis Partridge, n. sp.
 (Pl. 20, figs. 8, 9)

1973 *Aglaoreidia* sp. A, Stover & Evans (in press).

DESCRIPTION: Pollen monoporate, spherical to ellipsoidal, specimens commonly folded. Exine 0.5 to $1.0\ \mu$ thick, nexine thinner than sexine; sexine reticulate, muri delicate, narrow, and underlain by single columellae; lumina polygonal, fairly uniform in size.

1.0 to 1.5 μ in diameter, smaller lumina may occur at intersections of some muri. Pore circular, 2 to 2.5 μ in diameter, nexine thickened adjacent to pore, forming an annulate ring about 2 μ wide. Reticulum extends to pore margin. Diameter 20 (28) 35 μ , 17 specimens measured.

COMPARISON: *Aglaoeidia qualumis* differs from *A. cyclops* Erdtman 1960 by having the mesh of the reticulum fairly uniform in size whereas on *A. cyclops* the lumina are conspicuously smaller across the narrow ends of the pollen and apparently in the proximal polar area as well. The new species is also smaller than *A. cyclops* and has a smaller pore.

HOLOTYPE: Specimen on slide P29827, 32 μ in diameter.

TYPE LOCALITY AND STRATA: Rosedale-1 well at 2098-2100 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: Upper part of Lower *Nothofagidites asperus* Zone into the lower part of the *Proteacidites tuberculatus* Zone; late Eocene to early Oligocene.

Genus *Milfordia* Erdtman emended Partridge

1960 *Milfordia* Erdtman, p. 46.

1966 *Monulcpollenites* Fairchild in Stover, Elsik & Fairchild, p. 2, 3.

1968 *Restioniidites* Elsik, p. 313.

Type Species: *Milfordia hypolaenoides* Erdtman 1960, monotypic when proposed.

DIAGNOSIS (Emended): Pollen spherical to ellipsoidal, monoaperturate, porate or ulcate. Aperture variable, small to large, circular to elliptical, annulate or with irregular, ragged margin. Sexine about as thick as nexine, former foveolate, punctate or scrobiculate.

REMARKS: The aperture on the holotype is interpreted as ulcate rather than colpate, which automatically makes *Restioniidites* Elsik a synonym of *Milfordia*. Elsik (1968), in addition to diagnosing *Restioniidites* as incorporating monulcoid pollen, pointed out that the aperture type varies from porate and with or without an annulus to ulcate with irregular, broken margins.

Milfordia homeopunctata (McIntyre) Partridge n. comb.

(Pl. 21, figs. 10, 11)

1965 *Monoporopollenites homeopunctatus* McIntyre, p. 206, figs. 4, 5.

STRATIGRAPHIC RANGE: Within the *Malvacipollis diversus* Zone through the *Triporopollenites bellus* Zone, early Eocene through Miocene.

REMARKS: Specimens of *Milfordia homeopunctata* have an equatorial diameter of 21 (35) 47 μ and occur consistently only in the youngest zone.

Diporate Pollen

Genus *Banksieaeidites* Cookson ex Couper 1954

Banksieaeidites arcuatus Stover, n. sp.

(Pl. 21, figs. 2-4)

DESCRIPTION: Pollen biaperturate, anisopolar, outline in equatorial view asymmetrical, one side strongly convex, opposite side straight or nearly so. Nexine thicker than sexine, exine layering clearly differentiated to obscure, usually distinct adjacent to the pores where the nexine is thickened slightly; exine 1 to 1.5 μ thick, sculpturing very finely puncto-reticulate. Pores about 3 μ in diameter, one at each narrow end of the pollen and each with encircling collar approximately 2 μ wide. Dimensions, 23 (27) 32 μ in length; 15 to 19 μ in height, 15 specimens.

COMPARISON: *Banksieaeidites arcuatus* differs from the type species, *B. elongatus*, by being smaller, by having smaller apertures and one strongly convex surface.

HOLOTYPE: Specimen on slide P28049, 25 x 16 μ .

TYPE LOCALITY AND STRATA: Bass-2 well at 4308 ft, *Proteacidites asperopolis* Zone, early Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through the Lower *Nothofagidites asperus* Zone, early, middle and late Eocene.

Banksieaeidites elongatus Cookson 1950 (not illustrated)

1950 *Banksieaeidites elongatus* Cookson, p. 170, Pl. 1, fig. 10.

1950 *Banksieaeidites minimus* Cookson, p. 169, Pl. 1, figs. 8, 9.

1954 *Banksieaeidites cf. elongatus* Cookson, Couper, p. 480, text-fig. 1, fig. 3.

1960 *Banksieaeidites minimus* Cookson Potonié p. 113, Pl. 7, fig. 140.

1960 *Banksieaeidites elongatus* Cookson, Harris, p. 90, Pl. 27, fig. 23.

STRATIGRAPHIC RANGE: Within the *Lygistepollenites balmei* Zone through the *Triporopollenites bellus* Zone, late Paleocene through Miocene.

REMARKS: Cookson (1950) separated *Banksieaeidites minimus* from *B. elongatus* on the difference in size between the two forms. Because intermediate size specimens occur in Gippsland Basin assemblages, and in fact are more common than the larger or smaller specimens, *B. minimus* and *B. elongatus* are interpreted as one species with the following size range: length 21 (37) 45 μ , width, 18 (23) 28 μ , pore diameter, 9 to 18 μ . The lectotype illustrated by Cookson (1950, Pl. 1, fig. 10) is on slide P29710, and the specimen also illustrated by Cookson (1950, Pl. 1, fig. 9) is on slide P29709.

Genus *Granodiporites* Varma & Rawat 1963

Granodiporites nebulosus Partridge, n. sp.

(Pl. 21, fig. 1)

DESCRIPTION: Pollen anisopolar, amb elliptical, end truncated, lateral view plano-convex. Pores 3 to 11 μ in diameter, simple or with beaded lip at edge of

nexine; exine 1.5 to 2.5 μ thick, nexine 1 to 1.5 μ thick, thicker than sexine, latter rugulate to striate, ridges and grooves less than 1 μ wide, sexinal surface with widely spaced low granulae less than 1 μ in diameter. Dimensions, 40 (49) 78 μ in length, polar diameter 23 (29) 40 μ , 9 specimens measured.

COMPARISON: Of the species of *Granodiporites* described by Varma and Rawat (1963) *G. nebulosus* differs from *G. piercei* and *G. sahnii* by having simple pores, and from *G. erdtmanii* by having proportionally smaller pores. The granulate sculpturing and lack of collars around the apertures distinguish *G. nebulosus* from species of *Banksiaeaidites*.

HOLOTYPE: Specimen on slide P29732, 78 x 40 μ .

TYPE LOCALITY AND STRATA: Loy Yang-842 bore at 483-486 ft, *Proteacidites tuberculatus* Zone, early Oligocene.

STRATIGRAPHIC RANGE: Upper *Nothofagidites asperus* Zone into the basal part of the *Proteacidites tuberculatus* Zone, late Eocene and early Oligocene.

Triporate Pollen

Genus *Gambierina* Harris 1972

Gambierina edwardsii (Cookson & Pike) Harris 1972
(Pl. 21, fig. 9)

1954 *Triorites edwardsii* Cookson & Pike, p. 214, Pl. 2, figs. 101, 105, 106 (not figs. 102-104, 107).

1965 ——— Cookson & Pike, Harris, p. 94, Pl. 28, fig. 1.

1968 ——— Cookson & Pike, Dettmann & Playford, p. 86, Pl. 8, fig. 21.

1972 *Gambierina edwardsii* (Cookson & Pike), Harris, p. 55, fig. 12, (re-illustration of specimen shown in Harris, 1965).

LECTOTYPE: Specimen on slide P29664, and illustrated by Cookson & Pike (1954, Pl. 2, fig. 101).

TYPE LOCALITY AND STRATA: Lal Lal-51 bore at 398 ft, *Lygistepollenites balmei* Zone equivalent, middle to late Paleocene.

STRATIGRAPHIC RANGE: Within *Tricolporites lillieii* Zone into the *Lygistepollenites balmei* Zone, Late Cretaceous to late Paleocene.

Gambierina rudata Stover, n. sp.
(Pl. 21, fig. 8)

1954 *Triorites edwardsii* Cookson & Pike, p. 214, Pl. 2, figs. 102-104, 107 (not figs. 101, 105, 106).

1968 *aff. Triorites edwardsii* Cookson & Pike, Dettmann & Playford, p. 86, Pl. 8, fig. 20.

1973 *Triorites edwardsii* Cookson & Pike, Stover & Evans (in press).

DESCRIPTION: Pollen isopolar, amb triangular to concavely triangular, apices moderately rounded, occasionally angular. Exine 1.5 to 2.5 μ thick, nexine thicker than sexine, stratification commonly indistinct except at the apertures where the thin, ill-defined columellate layer is usually discernible, sexine psilate or faintly and indistinctly sculptured. Triradiate band of darkened exine, centred at the poles and with its

rays extending into the interradial areas, occurs on some specimens. Apertures about 1.5 μ wide, 3 to 4 μ deep as seen in polar view, with the exine 3 to 4 μ thick next to the apertures, and lacking conspicuous 'nick' point. Dimensions, 25 (29) 34 μ in diameter, 20 specimens measured.

COMPARISON: *Gambierina rudata* is similar to *G. edwardsii* (Cookson & Pike) Harris; however, specimens of the latter have more deeply concave sides and somewhat straight rather than rounded apices, and smaller diameters. On most specimens of *G. edwardsii*, the 'nick' point within the aperture is well defined and an indentation is present at the middle of each interradial margin. Both of these features are either lacking or very poorly expressed on specimens of *G. rudata*. In addition, the exine at the apertures is thinner on specimens of *G. rudata* than on those of *G. edwardsii*.

HOLOTYPE: Specimen on slide P28063, 29 μ in diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 5508 ft, *Lygistepollenites balmei* Zone, late Paleocene.

STRATIGRAPHIC RANGE: *Nothofagidites senectus* Zone through the *Lygistepollenites balmei* Zone, Late Cretaceous (Senonian) to late Paleocene.

REMARKS: In the Gippsland Basin, *Gambierina rudata* is by far more abundant than *G. edwardsii*, and is particularly common within the *Tricolpites longus* Zone.

Genus *Proteacidites* Cookson ex Couper 1953
Proteacidites adenanthoides Cookson 1950
(Pl. 22, figs. 7, 8)

1950 *Proteacidites adenanthoides* Cookson, p. 172, 173, Pl. 2, fig. 21.

1953 ——— Cookson, Couper, p. 42, Pl. 9, fig. 137.

1953 ——— Cookson, Cookson, p. 467, Pl. 1, fig. 20.

1965 ——— Cookson, Harris, p. 91, Pl. 28, fig. 9.

COMMENTS ON THE LECTOTYPE: The slide containing the lectotype has been given the accession number P29669. The specimen is complete and excellently preserved, is slightly anisopolar with clearly differentiated exine, particularly along the interradial equatorial margin. Exine is slightly over 3 μ thick interradially, with the nexine about twice as thick as the sexine, both layers thin towards the apertures, around which the nexine is very thin to indistinguishable. Surface in non-apertural areas finely reticulate, lumina circular, elongate or chevron-shaped, occupy slightly less area than muri, columellae beneath muri singular and fairly regularly distributed. Reticulation finer in apertural areas, essentially puncto-reticulate, columellae indistinct. Pores concave in polar view, about 6 μ wide. Diameter 73 x 74.5 μ .

STRATIGRAPHIC RANGE: Upper part of *Lygistepollenites balmei* Zone through the Lower *Nothofagidites asperus* Zone, late Paleocene into late Eocene.

REMARKS: On some specimens the mesh of the reticulation is larger on one surface than on the other,

but not appreciably so. The difference is expressed by an increase in the size of the lumina. In addition, the nexine may thin only at the pores and maintain a constant thickness as seen along the equatorial margin. Size range is 44 to 75 μ in diameter; columellae tend to be indistinct on specimens less than 50 μ in diameter.

TYPE LOCALITY AND STRATA: Wensleydale, Victoria, about 10 miles NW. of Anglesea, lignite clay, Eocene, probably early Eocene, zone equivalent uncertain.

***Proteacidites alveolatus* Stover n. sp.**

(Pl. 22, figs. 1, 2)

DESCRIPTION: Pollen isopolar to slightly anisopolar, amb triangular with slightly convex to slightly concave sides. Exine stratification usually distinct; nexine 1 to 1.5 μ thick, tends to be indistinct in and around apertures, sexine about 1 μ thick, reticulate, muri 2 to 2.5 μ wide and outline somewhat circular to elliptical lamina 2.5 μ in length, mesh smaller towards apertures. Muri with widely scattered perforations less than 1 μ in diameter. Columellae more or less evenly distributed beneath muri, absent below lumina. Apertures porate, equatorial, concave in polar view, 3 to 5 μ across. Dimensions, 32 (38) 42 μ in diameter, 13 specimens measured.

COMPARISON: *Proteacidites alveolatus* differs from *P. kopiensis* Harris 1972 and *P. pseudomoides* Stover (this paper) by having wider muri so that a greater portion of the pollen surface is taken up by the muri than by the lumina. The new species has a thicker nexine than *P. pseudomoides* and the lumina are not conspicuously larger in the interradian areas as in *P. kopiensis*.

HOLOTYPE: Specimen on slide P28076, 40 μ in diameter.

TYPE LOCALITY AND STRATA: Marlin-3 well at 5088 ft, Latrobe Group, *Proteacidites asperopolus* Zone, early Eocene.

STRATIGRAPHIC RANGE: Upper part of *Malvacipollis diversus* Zone into the lower part of the Lower *Nothofagidites asperus* Zone, early and middle Eocene.

***Proteacidites amolosexinus* Dettmann & Playford 1968**

(not illustrated)

1968 *Proteacidites amolosexinus* Dettmann & Playford, p. 87, Pl. 8, figs. 15-18.

STRATIGRAPHIC RANGE: *Nothofagidites senectus* through *Tricolpites longus* Zones, Late Cretaceous to early Paleocene, possibly middle Paleocene.

***Proteacidites angulatus* Stover, n. sp.**

(Pl. 22, figs. 5, 6)

DESCRIPTION: Pollen usually isopolar, occasional specimens slightly anisopolar; amb triangular, apices somewhat protrusive, truncated, sides straight to slightly convex. Exine clearly stratified; nexine 1 to 1.5 μ thick, uniform in thickness or thinner at apertures, sexine about as thick as nexine, columellate layer and ectosexine of approximately equal thickness. Sexine reticulate over most of the pollen surface, puncto-reticulate in apertural areas, lumina and muri

small, usually less than 1 μ in width, fairly regular in size. Pores shallowly concave in polar view, 3 to 5 μ in width. Dimensions, 23 (30) 34 μ , 12 specimens measured.

COMPARISON: *Proteacidites angulatus* differs from *P. reticulosabratus* Harris 1965 by having protrusive, nonscabrate apertural areas, a smaller mesh reticulum and a generally smaller size.

HOLOTYPE: Specimen on slide P28091, 30 μ in diameter.

TYPE LOCALITY AND STRATA: Barracouta-1 well at 7251 ft, Latrobe Group, *Lygistepollenites balmei* Zone, middle Paleocene.

STRATIGRAPHIC RANGE: *Tricolpites longus* into the *Lygistepollenites balmei* Zone, early and middle Paleocene.

***Proteacidites annularis* Cookson 1950**
(not illustrated)

1950 *Proteacidites annularis* Cookson, p. 170, Pl. 1, fig. 15.

1953 ——— Cookson, Couper, p. 42, Pl. 5, fig. 52.

1953 *Proteacidites granulatus* Cookson, p. 467, Pl. 1, fig. 23.

1953 *Proteacidites annularis* Cookson, Cookson, p. 466, Pl. 1, fig. 19.

1960 ——— Cookson, Couper, p. 49, Pl. 5, figs. 11, 12.

1965 ——— Cookson, Harris, p. 92, Pl. 28, figs. 12, 13.

1973 ——— Cookson, Stover & Evans, (in press).

STRATIGRAPHIC RANGE: *Lygistepollenites balmei* Zone through the *Triplopollenites bellus* Zone, middle Paleocene through Miocene.

REMARKS: In 1950 Cookson described in detail the apertures and internal exine morphology of *Proteacidites annularis*. Three years later she reiterated the characteristics of *P. annularis* and in the same publication (Cookson, 1953) named a new species, *P. granulatus*. Based on the examination of 50 well preserved specimens from the Gippsland Basin and on comparisons with the specimens illustrated by Cookson in 1950 and 1953, the two forms are conspecific. Because *P. annularis* has priority over *P. granulatus*, the former name is applied to specimens that range in size between 25 and 50 μ , have distinct apertural collars, and a finely granulate to irregularly scabrate sexine.

***Proteacidites asperopolus* Stover & Evans 1973**
(Pl. 26, fig. 2)

1973 *Proteacidites asperopolus* Stover & Evans (in press).

STRATIGRAPHIC RANGE: Upper part of *Malvacipollis diversus* Zone into the lower part of the Lower *Nothofagidites asperus* Zone, early Eocene into middle Eocene.

***Proteacidites beddocii* Stover, n. sp.**
(Pl. 22, figs. 3, 4)

DESCRIPTION: Pollen isopolar, amb triangular, sides straight to slightly convex. Exine stratification distinct,

nexine thicker than or as thick as sexine, exine $1.5\ \mu$ thick between apertures, slightly thinner around apertures on some specimens. Columellate layer composed of dense, evenly distributed, minute columellae that in polar view provide a faint, granular pattern, outer exinal surface with small, scattered apiculae. Pores about $3\ \mu$ wide in polar view, nexine roughened and/or thickened slightly around pores on some specimens. Dimensions, 20 (24) $30\ \mu$ in diameter, 22 specimens measured.

COMPARISON: *Proteacidites beddoesii* differs from *P. parvus* Cookson 1950 by having an apiculate sexine, a convexly triangular equatorial outline and generally some scabration within the apertures.

HOLOTYPE: Specimen on slide P28049, $25\ \mu$ in diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 4308 ft, *Proteacidites asperopolus* Zone, early Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through the Lower *Nothofagidites asperus* Zone, early to late Eocene.

***Proteacidites crassus* Cookson 1950**
(Pl. 22, fig. 9)

1950 *Proteacidites crassus* Cookson, p. 173, Pl. 2, fig. 22.

COMMENTS: The lectotype is strongly anisopolar, reticulate, muri 1 to $1.5\ \mu$ wide and lumina from 0.5 to $2.5\ \mu$ in length. The columellae beneath the muri are distinct, single or paired, closely spaced, and the pores are about $5\ \mu$ wide as seen in polar view. Other morphologic features are as described by Cookson (1950).

LECTOTYPE: Specimen on slide P29695, $63\ \mu$ in diameter and illustrated by Cookson (1950, Pl. 2, fig. 22), here designated.

TYPE LOCALITY AND STRATA: Moorlands Coalfield, South Australia, Moorlands lignite member of Renmark Beds, late Eocene, Lower *Nothofagidites asperus* Zone equivalent.

STRATIGRAPHIC RANGE: *Proteacidites asperopolus* Zone through the Lower *Nothofagidites asperus* Zone, early to late Eocene.

***Proteacidites grandis* Cookson 1950**
(Pl. 23, fig. 3)

1950 *Proteacidites grandis* Cookson, p. 173, Pl. 2, fig. 23.

1965 *Proteacidites dilwynensis* Harris, p. 93, Pl. 28, figs. 27, 28.

1973 ——— Harris, Stover & Evans (in press).

COMMENTS: The lectotype is here designated as the specimen illustrated by Cookson (1950) and located on slide P29669. The muri of the sexinous reticulum are about $1\ \mu$ wide and the lumina are irregularly shaped with their greatest dimension being from 2 to $4\ \mu$. Muri supported by single and paired, rather closely spaced columellae which become denser towards the apertures as the size of the lumina is decreased. The mesh of the reticulum is very fine around

the apertures as illustrated by Harris (1965, Pl. 28, fig. 28). Lectotype is $80 \times 84\ \mu$ in diameter.

Specimens of *Proteacidites grandis* tend to be slightly anisopolar and the reticulation at one pole may be fractionally larger than on the other pole. Shape of the pollen in polar view varies from moderately to strongly concavely triangular.

TYPE LOCALITY AND STRATA: Wensleydale, Victoria, about 10 miles NW. of Anglesea, lignitic clay, Eocene, probably early Eocene, zone equivalent unknown.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* and *Proteacidites asperopolus* Zones, early Eocene.

***Proteacidites incurvatus* Cookson 1950**
(Pl. 25, fig. 8)

1950 *Proteacidites incurvatus* Cookson, p. 171, Pl. 2, figs. 25, 26.

1965 ——— Cookson, Harris, p. 92, Pl. 28, fig. 5.

DESCRIPTION (Revised): Pollen isopolar, amb concavely triangular with moderately rounded apices. Exine stratification distinct, exine $6\ \mu$ thick in interradial—equatorial areas, $4\ \mu$ thick at apertures; nexine and sexine approximately equal in thickness. Columellae dense, relatively small, psilate, tips of adjacent columellae commonly coalesced to form low granulae, tuberculae or rounded verrucae from slightly less than $1\ \mu$ to $6\ \mu$ in diameter, sculpturing uniform or variable on individual specimens, coarser sculpturing usually in the polar and/or interradial areas. Pores 8 to $14\ \mu$ wide, outer margin concave in polar view. Dimensions, 63 (75) $102\ \mu$ in diameter, 10 specimens measured.

LECTOTYPE: Specimen on slide P29693, and illustrated by Cookson (1950, Pl. 2, fig. 25) $96 \times 102\ \mu$.

TYPE LOCALITY AND STRATA: Moorlands Coalfield, South Australia, Moorlands lignite member of Renmark Beds, late Eocene.

STRATIGRAPHIC RANGE: Upper part of *Lygistepollenites balmei* Zone into the Lower *Nothofagidites asperus* Zone, late Paleocene through middle Eocene.

***Proteacidites kopiensis* Harris 1972**
(not illustrated)

1972 *Proteacidites kopiensis* Harris, p. 57, figs. 26, 27.

1973 *Proteacidites* sp. B, Stover & Evans, (in press).

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone into the Lower *Nothofagidites asperus* Zone, early Eocene into late Eocene.

***Proteacidites latrobensis* Harris 1966**
(Pl. 25, fig. 5)

1965 *Proteacidites crassipora* Harris, p. 93, Pl. 28, figs. 24, 25.

1966 *Proteacidites latrobensis* Harris, p. 332.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through the Lower *Nothofagidites asperus* Zone, early to late Eocene.

REMARKS: Specimens of *Proteacidites latrobensis*, including the holotype, have scattered apiculae on the

sexine; the presence of apiculae is characteristic and one of the diagnostic features of the species.

***Proteacidites leightonii* Stover, n. sp.**
(Pl. 23, figs. 1, 2)

1965 *Proteacidites grandis* Cookson, Harris, p. 92, Pl. 29, fig. 1.

1973 ——— Cookson, Stover & Evans, (in press).

DESCRIPTION: Pollen isopolar to anisopolar, amb concavely triangular; exine clearly stratified, exine 5 to 6 μ thick between apertural areas, about 4 μ thick around apertures; sexine thicker than nexine except around apertures where the sexine and nexine are of approximately equal thickness. Sexine coarsely reticulate, lumina and muri psilate, muri 1.5 to 2 μ wide, narrower around apertures, outline of lumina irregular, size variable, 2 to 15 μ in length, average about 6 μ , lumina tend to be larger at one polar area. Columellae underlie muri, absent within lumina, single or paired, closely spaced. Apertures slightly concave in polar view, about 6 μ wide. Dimensions, 62 (66) 75 μ in diameter, 25 specimens measured.

COMPARISON: *Proteacidites leightonii* differs from *P. grandis* Cookson 1950 by having a larger mesh reticulation and a thicker exine, and from *P. reticulatus* by being larger.

HOLOTYPE: Specimen on slide P28049, 63 μ in diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 4308 ft, *Proteacidites asperopolus* Zone, early Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* through Lower *Nothofagidites asperus* Zone, early Eocene to late Eocene.

REMARKS: Medium to large size, generally reticulate proteaceous pollen are a conspicuous component of early Eocene palynomorph assemblages from the Latrobe Group. These pollen are more or less typified by *Proteacidites leightonii*. Smaller specimens with the same morphology have been identified as *P. reticulatus*. Although Harris (1965) states what he believes are the distinguishing differences among *P. leightonii* (as *P. grandis*), *P. grandis* (as *P. dilwynensis*) and *P. ornatus* Harris 1965, intermediate forms occur, and it is frequently difficult to consistently separate these three species with reasonable confidence. Retention of the three species is justified because each has a different stratigraphic range.

***Proteacidites ornatus* Harris 1965**
(not illustrated)

1965 *Proteacidites ornatus* Harris, p. 83, Pl. 28, figs. 22, 23, 24.

STRATIGRAPHIC RANGE: Upper part of the *Malvacipollis diversus* Zone and the *Proteacidites asperopolus* Zone, early Eocene.

***Proteacidites obscurus* Cookson 1950**
(Pl. 25, fig. 4)

1950 *Proteacidites obscurus* Cookson, p. 175, Pl. 3, figs. 30, 31.

1972 *Proteacidites varius* Harris, p. 58, figs. 39-42.

LECTOTYPE: Specimen on slide P29694, and illustrated by Cookson (1950, Pl. 3, fig. 30).

TYPE LOCALITY AND STRATA: Moorlands Coalfield, South Australia, Moorlands lignite member of the Renmark Beds, late Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through the *Triplopollenites bellus* Zone, early Eocene to late Miocene.

REMARKS: The sexine appears to be attached weakly to the nexine because specimens are commonly found in which the sexine is stripped with only remnants remaining, usually around the apertures.

***Proteacidites pachypolus* Cookson & Pike 1954**
(Pl. 26, fig. 1)

1954 *Proteacidites pachypolus* Cookson & Pike, p. 208, Pl. 2, figs. 64-66.

1954 ——— Cookson & Pike, Cookson, fig. 2a.

1965 ——— Cookson & Pike, Harris, p. 91, Pl. 28, fig. 7.

1973 ——— Cookson & Pike, Stover & Evans, (in press).

LECTOTYPE: Specimen on slide P29678 and illustrated by Cookson and Pike (1954, Pl. 2, fig. 64), 39 μ in diameter.

TYPE LOCALITY AND STRATA: South Australian Department of Mines Canopus Station-1 bore, carbonaceous sandstone at 881-910 ft, Eocene.

STRATIGRAPHIC RANGE: Upper part of *Malvacipollis diversus* Zone into the Lower *Nothofagidites asperus* Zone, early Eocene into the late Eocene.

REMARKS: Another specimen of *Proteacidites pachypolus* illustrated by Cookson and Pike (1954, Pl. 2, fig. 66) is on slide P29654.

***Proteacidites palisadus* Couper 1953**
(not illustrated)

1953 *Proteacidites palisadus* Couper, pp. 42, 43, Pl. 5, fig. 54.

1960 ——— Couper, Couper, p. 49, Pl. 5, fig. 17.

1973 ——— Couper, Stover and Evans, (in press).

STRATIGRAPHIC RANGE: *Tricolporites lilliei* Zone into the *Tricolpites longus* Zone, late Cretaceous into early Paleocene.

REMARKS: In size and exine thickness, the Australian specimens are intermediate between those of *P. palisadus* and *P. subpalisadus* Couper 1953. The specimens are assigned to *P. palisadus* because the exine thickness (2 to 3.5 μ) is more similar to that for this species than for *P. subpalisadus*.

***Proteacidites pseudomoides* Stover, n. sp.**
(Pl. 25, fig. 3)

DESCRIPTION: Pollen isopolar to slightly anisopolar, amb triangular, sides straight or very gently concave. Exine stratification distinct, nexine and sexine about equally thick, exine 1 μ or slightly more than 1 μ , nexine may be thinner around the apertures than between them. Columellae indistinct, sexine reticulate, muri narrow, about 0.5 μ wide, lumina circular to

polygonal, 0.5 to 2 μ in diameter, tend to be coarsest near the equator between apertural areas. Pores concave in polar view, 4 to 5 μ across. Dimensions, 27 (31) 36 μ , 30 specimens measured.

COMPARISON: *Proteacidites pseudomoides* differs from *P. symphyonemoides* Cookson 1950 by having a thinner exine, an indistinct columellate layer, and a more irregularly shaped, generally smaller meshed reticulum. Although the lumina of *P. pseudomoides* may be coarser interradially, the lumina do not approach the size of those developed on *P. kopiensis* Harris 1972.

HOLOTYPE: Specimen on slide P28074, 30 μ in diameter.

TYPE LOCALITY AND STRATA: Marlin-3 well at 5127 ft, Latrobe Group, *Proteacidites asperopolus* Zone, early Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* into the *Proteacidites tuberculatus* Zones, early Eocene into early Oligocene.

***Proteacidites recavus* Partridge, n. sp.**
(Pl. 24, fig. 4, 5)

DESCRIPTION: Pollen slightly anisopolar, amb triangular, sides moderately concave to straight, apices broadly rounded. Exine 3 to 4 μ thick interradially, thinner around apertures, sexine thinner than nexine, latter 2 to 4 μ thick interradially, slightly recurved at pores, sexine reticulate, muri 0.5 to 1 μ wide, labyrinthine, in some areas discontinuous, segments straight or curved. Lumina irregular, greatest dimension 1.5 to 3 μ , columellae beneath muri singular, vague to distinct. Mesh of reticulum largest in polar areas, smallest around apertures. Pore margins shallowly concave in polar view, pores 8 to 13 μ wide. Dimensions, 52 (59) 80 μ , 10 specimens measured.

COMPARISON: *Proteacidites recavus* differs from *P. incurvatus* Cookson 1950 and *P. stipplatus* Partridge (this paper) by having a reticulate sexine; from the latter only *P. recavus* differs by having predominantly concave sides and the exine recurved slightly at the apertures.

HOLOTYPE: Specimen on slide P29860, 52 μ in diameter.

TYPE LOCALITY AND STRATA: Coolungoolun-1 bore at 290 ft, Lower *Nothofagidites asperus* Zone, middle Eocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone, middle and late Eocene.

***Proteacidites rectomarginis* Cookson 1950**
(Pl. 23, figs. 6-8)

1950 *Proteacidites rectomarginis* Cookson, pp. 174, 175, Pl. 2, fig. 27.

1972 *Proteacidites clintonensis* Harris, p. 57, figs. 30-34.

DESCRIPTION (Revised): Pollen isopolar, amb triangular with straight to slightly concave sides with slightly truncated apices. Exine 3 to 5 μ thick, nexine 1.5 to 2.5 μ interradially, up to 3.5 μ thick at aper-

tures where it is disrupted by grooves and punctae, imparting a ragged appearance to a zone up to 10 μ wide around the apertures. Sexine tectate, 1.5 to almost 2 μ thick, of uniform thickness, columellae distinct, single, about 0.5 μ in diameter and 0.5 to 1.5 μ apart. Sexine above tectum granulate to verrucate, latter 0.5 to 3 μ in diameter (average 1.5 to 2 μ), of fairly constant size on individual pollen, shape variable, separated by narrow grooves which together with the verrucae form a negative reticulum; grooves with fine punctae which pierce the tectum. Usually triporate, occasional specimens di- or tetraporate, pores 8 to 14 μ wide in polar view, outline ragged. Dimensions, 40 (53) 60 μ , 24 specimens measured.

COMPARISON: *Proteacidites rectomarginis* is similar to *P. incurvatus*; the latter differs by having rounded, slightly incurved apices, the exine thinning rather than thickening toward the apertures and by having the supratragellar sculpturing distinctly coarser in the interradiial areas than over the rest of the pollen surface.

LECTOTYPE: Specimen on slide P29657, 84 μ in diameter and illustrated by Cookson (1950, Pl. 2, fig. 27).

TYPE LOCALITY AND STRATA: Lucifer Mine, 0.5 miles SE. of Bacchus Marsh railway station, Victoria, Maddingley seam, *Proteacidites tuberculatus* Zone equivalent, early Miocene.

STRATIGRAPHIC RANGE: Within Lower *Nothofagidites asperus* Zone into the *Triplopollenites bellus* Zone, late Eocene into late Miocene.

REMARKS: The revised description is based on the study of topotype specimens as well as material from the Gippsland Basin.

***Proteacidites reflexus* Partridge, n. sp.**
(Pl. 24, fig. 6)

DESCRIPTION: Pollen slightly anisopolar, amb triangular, sides straight to faintly undulate, apices narrow and blunt, biconvex in equatorial view. Triporate, pores 5 to 8 μ in diameter. Exine 3 to 3.5 μ thick at the poles and interradially, nexine thicker than sexine; columellate layer thinner than tectum, columellae large and irregular, 0.5 to 1 μ in diameter, some elongate up to 2 μ long and 1 μ wide, others with less regular shapes. Tectum complete with evenly distributed, constant size perforations, 0.5 μ in diameter. Collars of thin exine, 14 to 18 μ wide, developed around apertures and distinguished by a marked thinning of the exine to less than 1 μ . Nexine thickness uncertain, layer obscure. Columellate layer and tectum thinner, and the columellae and perforations are smaller over the collars than in the polar areas. Dimensions, equatorial diameter 40 (51) 59 μ , 14 specimens measured.

COMPARISON: The marked differential thickening of the exine and the coarse columellate layer in the polar areas serve to distinguish *Proteacidites reflexus* from other species of *Proteacidites*.

HOLOTYPE: Specimen on slide P29856, 59 μ in diameter.

TYPE LOCALITY AND STRATA: Rosedale-1 well at 2287 ft, Lower *Nothofagidites asperus* Zone, middle Eocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone, middle and late Eocene.

***Proteacidites reticulatus* Cookson 1950**
(Pl. 23, figs. 4, 5)

1950 *Proteacidites reticulatus* Cookson, p. 174, Pl. 1, fig. 24.

DESCRIPTION (Revised): Pollen isopolar, amb triangular, sides slightly to strongly concave, apices straight or nearly so. Exine 2.5 to 3 μ thick interradially, about 2 μ thick at the apertures, nexine and sexine of about equal thickness, columellae distinct, single or paired. Sexine reticulate, muri about 2 μ wide over most of the surface, about 1 μ wide at apertures; lumina irregularly polygonal, longest dimension 3 to 9 μ over most of the surface, more or less circular and 1 μ or less at apertures. Pores 3 to 4 μ wide, usually poorly delimited. Dimensions, 25 (37) 43 μ , 16 specimens measured.

COMPARISON: *Proteacidites reticulatus* is morphologically quite similar to *P. leightonii* Stover, from which it differs by being considerably smaller.

NEOTYPE: Specimens on slide P29694, 36 μ in diameter. Because efforts to locate the specimen illustrated by Cookson (1950, Pl. 1, fig. 24) have been unsuccessful, a neotype is selected from one of Dr. Cookson's preparations of the Moorlands Brown Coal.

TYPE LOCALITY AND STRATA: Moorlands Coalfield, South Australia, Moorlands lignite member of Renmark Beds, late Eocene, Lower *Nothofagidites asperus* Zone equivalent.

STRATIGRAPHIC RANGE: Within the *Malvacipollis diversus* Zone into the Lower *Nothofagidites asperus* Zone, early Eocene into late Eocene.

***Proteacidites reticulosabratatus* Harris 1965**
(not illustrated)

1965 *Proteacidites reticulosabratatus* Harris, p. 93, Pl. 28, figs. 20, 21.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through the Lower *Nothofagidites asperus* Zone, early Eocene into late Eocene.

***Proteacidites stipplatus* Partridge, n. sp.**
(Pl. 24, figs. 2, 3)

DESCRIPTION: Pollen isopolar, amb triangular, sides straight or nearly so, apices truncated. Exine 3 to 4.5 μ thick, nexine 2 to 3.5 μ thick, sexine with closely spaced granulae or less commonly with circular to elongate tuberculae, 1 μ or less in diameter, 2 to 3 μ long, about 0.5 μ in height and of fairly constant size on individual specimens. Distances between granulae less than their diameters, may be more widely spaced particularly when granules are coalesced to form short, arcuate to sinuous ridges. Columellae usually distinct on specimens with fine sculpturing, less distinct or not discernible on those with coarse sculpturing.

Pore margins concave in polar view, somewhat depressed, pores 6 to 11 μ wide. Dimensions, 39 (51) 68 μ in diameter, 20 specimens measured.

COMPARISON: *Proteacidites stipplatus* differs from *P. recavus* by having straight sides and granulate to tuberculate rather than reticulate sculpturing. The small size and density of the sculpturing serve to distinguish the new species from *P. tuberculatus*.

HOLOTYPE: Specimen on slide P29757, 48 μ in diameter.

TYPE LOCALITY AND STRATA: Loy Yang-842 bore at 483-486 ft, *Proteacidites tuberculatus* Zone, early Oligocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone into the *Proteacidites tuberculatus* Zone, late Eocene into Oligocene.

***Proteacidites symphyonemoides* Cookson 1950**
(Pl. 25, figs. 1, 2)

1950 *Proteacidites symphyonemoides* Cookson, p. 172, Pl. 2, fig. 17.

DESCRIPTION (Revised): Pollen slightly anisopolar, amb triangular, sides straight to slightly concave, apices truncated. Exine 2 to 2.5 μ thick, nexine and sexine approximately equal in thickness, sexine reticulate. Muri 1 to 1.5 μ wide, convolute, lumina irregular, 1.5 to 3 μ in maximum length, mesh of reticulum fairly uniform over entire pollen, muri underlain by single and paired columellae. Pores 4 μ in diameter, outer margin straight in polar view. Dimensions, equatorial diameter 22 (26) 35 μ , 10 specimens measured.

LECTOTYPE: Specimen on slide P29670, 34.5 μ in diameter, and illustrated by Cookson (1950, Pl. 1, fig. 17).

TYPE LOCALITY AND STRATA: Yallourn Open Cut, Victoria, clay at base of Yallourn Coal seam, *Triporopollenites bellus* Zone, late Miocene.

STRATIGRAPHIC RANGE: *Triporopollenites bellus* Zone, late Miocene.

REMARKS: Although small reticulate specimens of *Proteacidites* are common in Eocene assemblages, none appear conformable with *P. symphyonemoides* and there is a distinct stratigraphic discontinuity between the Eocene forms and the late Miocene occurrence of *P. symphyonemoides*. In the *Proteacidites tuberculatus* Zone, small reticulate species are absent or different morphologically from *P. symphyonemoides*. The specimens illustrated by Harris (1965) and by Couper (1960) identified as *P. symphyonemoides*, probably belong to another species.

***Proteacidites tenuixinus* Stover, n. sp.**
(Pl. 25, figs. 6, 7)

DESCRIPTION: Pollen isopolar to slightly anisopolar, amb convexly triangular. Exine stratification faint to distinct, exine slightly over 1 μ thick, nexine extremely thin, tends to be thicker around the apertures than between them. Sexine granulate to unevenly scabrate. Pore margins gently concave in polar view, 4 to 6 μ

wide. Dimensions, 29 (33) 36 μ in diameter, 17 specimens measured.

COMPARISON: The convexly triangular outline, thin exine and scabrate to granulate sculpturing are characteristic of the species, which collectively serve to separate *Proteacidites tenuixinus* from other *Proteacidites* species of similar size.

HOLOTYPE: Specimen on slide P28085, 35 μ in diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 3996 ft, Lower *Nothofagidites asperus* Zone, middle Eocene.

STRATIGRAPHIC RANGE: Upper part of *Lygistepollenites balnei* Zone into the Lower *Nothofagidites asperus* Zone, late Paleocene to middle Eocene.

***Proteacidites tuberculatus* Cookson 1950**
(Pl. 24, fig. 1)

1950 *Proteacidites tuberculatus* Cookson, p. 170, Pl. 1, figs. 12-14.

LECTOTYPE: Specimen on slide P29674, 111 μ in diameter and illustrated by Cookson (1950, Pl. 1, fig. 13), here designated.

TYPE LOCALITY AND STRATA: Yallourn Open Cut, Victoria, Yallourn Coal Seam at 92 ft, below the top of the seam, *Triporopollenites bellus* Zone, late Miocene.

STRATIGRAPHIC RANGE: Upper *Nothofagidites asperus* Zone through the *Triporopollenites bellus* Zone, late Eocene through late Miocene.

***Proteacidites tuberculiformis* Harris 1965**
(not illustrated)

1965 *Proteacidites tuberculiformis* Harris, p. 92, Pl. 29, figs. 5-7.

STRATIGRAPHIC RANGE: Within the *Malvacipollis diversus* Zone through the Lower *Nothofagidites asperus* Zone, early Eocene into late Eocene.

Genus *Triorites* Cookson emended Potonié 1960
***Triorites magnificus* Cookson 1950**
(Pl. 25, fig. 9)

1950 *Triorites magnificus* Cookson, pp. 175, 176, Pl. 3, figs. 32-35.

1960 ——— Cookson *ex Couper*, Potonié, p. 128, Pl. 8, fig. 175.

1973 ——— Cookson, Stover & Evans (in press).

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone, late Eocene.

Genus *Triporopollenites* Pflug & Thomson 1953
***Triporopollenites ambiguus* Stover, n. sp.**
(Pl. 21, fig. 7)

DESCRIPTION: Pollen isopolar, amb triangular, sides straight or slightly convex. Exine undifferentiated, relatively thin (about 1 μ thick), thickened slightly around apertures, surface with widely scattered apiculae and with or without occasional granulae. Pores in polar view 5 to 7 μ wide, outline concave. Dimensions, 34 (40) 48 μ in diameter, 10 specimens measured.

COMPARISON: *Triporopollenites ambiguus* differs from *T. chnosus* Partridge (this paper) by having a thinner exine with apiculae.

HOLOTYPE: Specimen on slide P28049, 46 μ in diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 4308 ft, *Proteacidites asperopolis* Zone, early Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through the Lower *Nothofagidites asperus* Zone, early Eocene into the late Eocene.

***Triporopollenites bellus* Partridge, n. sp.**
(Pl. 27, figs. 9, 10)

DESCRIPTION: Pollen isopolar, spherical to oblate, amb circular. Majority of specimens triporate, others with 2, 4, or 5 equatorial pores, pores circular, 2 to 3 μ in diameter and annulate, annuli about 2 μ wide and up to 2.5 μ thick. Exine 2 μ thick equatorially, up to 3.5 μ thick at the poles, nexine and sexine of equal thickness at the equator, both layers thicker at the poles, the nexine less so than the sexine, latter reticulate. Columellae single or paired and underlie narrow muri, also occur in a row around, but not on, the annuli. Lumina irregularly polygonal, from less than 2 μ in diameter. Dimensions, equatorial diameter 15 (20) 32 μ , polar diameter 20 (22) 24 μ for specimens having an equatorial diameter between 17 and 22 μ , 29 specimens measured.

COMPARISON: *Triporopollenites bellus* differs from other Australian species of the genus by having a circular equatorial outline, a reticulate sexine, annulate pores and from 2 to 5 pores.

HOLOTYPE: Specimen on slide P29831, 22 x 23 μ .

TYPE LOCALITY AND STRATA: Rosedale-1 well at 476-480 ft, *Triporopollenites bellus* Zone, late Miocene.

STRATIGRAPHIC RANGE: *Triporopollenites bellus* Zone, late Miocene.

***Triporopollenites chnosus* Partridge, n. sp.**
(Pl. 21, fig. 6)

DESCRIPTION: Pollen anisopolar, concavo-convex in equatorial view, amb triangular, sides convex. Pores in polar view 5 to 8 μ wide, outline concave, and may be covered by a thin membrane. Exine 2 to 2.5 μ thick, nexine thicker than sexine, latter less than 0.5 μ , surface scabrate to very finely punctate, columellae not discernible. Dimensions, equatorial diameter 36 (45) 54 μ , 12 specimens measured.

COMPARISON: Consult comparison for *Triporopollenites ambiguus*.

HOLOTYPE: Specimen on slide P29821, 46 μ in diameter.

TYPE LOCALITY AND STRATA: Glencoe-4 well at 280 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: Within the Lower *Nothofagidites asperus* Zone through the *Triporopollenites bellus* Zone, late Eocene through Miocene.

***Triporopollenites sectilis* Stover, n. sp.**

(Pl. 21, fig. 5)

1973 *Triporopollenites* sp. A, Stover & Evans (in press).

DESCRIPTION: Pollen isopolar, amb concavely triangular, apices broadly rounded to truncate. Exine slightly less than $2\ \mu$ thick, vaguely to moderately well differentiated, nexine thicker than sexine, latter psilate to irregularly roughened, columellae not discernible. Pores elongate, appear slit-like in polar view, 4 to $6\ \mu$ wide. Dimensions, equatorial diameter 27 (31) $35\ \mu$, 14 specimens measured.

COMPARISON: *Triporopollenites sectilis* differs from *T. chnosus* by being smaller and by having a concavely triangular equatorial outline.

HOLOTYPE: Specimen on slide P28093, $31\ \mu$ in diameter.

TYPE LOCALITY AND STRATA: Barracouta-1 well at 8695 ft, Latrobe Group, *Tricolporites lilliei* Zone, Late Cretaceous.

STRATIGRAPHIC RANGE: *Tricolporites lilliei* and *Tricolporites longus* Zones, late Cretaceous to early Paleocene, possibly middle Paleocene.

Hexaporate Pollen**Genus *Anacolosidites* Cookson & Pike 1954*****Anacolosidites acutullus* Cookson & Pike 1954**

(Pl. 27, fig. 1)

1954 *Anacolosidites acutullus* Cookson & Pike, p. 208, Pl. 1, figs. 62, 63.

1965 ——— Cookson & Pike, Harris, p. 94, Pl. 27, figs. 27, 28.

DESCRIPTION (Revised): Amb triangular, sides slightly convex, corners moderately rounded. Exine 1.5 to just over $3\ \mu$, thinnest in the areas adjacent to the corners and thickest in the central marginal areas. Nexine 1 to $2\ \mu$, thicker than sexine; outer surface of sexine appears psilate and continuous, columellate layer composed of discrete, more or less circular rodlets about $0.75\ \mu$ in diameter plus short, straight or curved elevations whose lengths are 2 to 4 times their widths, the latter being about $1\ \mu$, columellate ridges largest in the polar areas, and those on one polar area slightly coarser than those on the opposite polar area. Apertures circular, $4\ \mu$ in diameter, located approximately $10\ \mu$ from the corners of the equatorial margin (some apertures are elliptical— $5.5 \times 3\ \mu$, however the apparent elongation may be due to compression).

LECTOTYPE: Specimen on slide P29661, $41.5 \times 43\ \mu$ in diameter and illustrated by Cookson & Pike (1954, Pl. 1, fig. 62).

TYPE LOCALITY AND STRATA: Birregurra-1 bore at 842-843 ft, Lower *Nothofagidites asperus* Zone equivalent, middle Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone to the basal part of the Lower *Nothofagidites asperus* Zone, early to middle Eocene.

REMARKS: The supplementary description is based primarily on the lectotype. We were unable to locate the other specimen of *Anacolosidites acutullus* illustrated by Cookson and Pike. Specimens from the Gippsland Basin are generally less well preserved and the elevations in the columellate layer are slightly smaller than those on the lectotype.

***Anacolosidites luteoides* Cookson & Pike 1954**

(Pl. 27, fig. 6)

1954 *Anacolosidites luteoides* Cookson & Pike, p. 207, Pl. 1, fig. 50, not figs. 47-49.

1959 ——— Cookson & Pike, Krutzsch, p. 244, (selected as lectotype the specimen illustrated as fig. 50 of Pl. 1 in Cookson & Pike, 1954).

1965 ——— Cookson & Pike, Harris, p. 94, Pl. 27, fig. 29.

1968 ——— Cookson & Pike, McIntyre, p. 195, figs. 55, 56.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone into the Lower *Nothofagidites asperus* Zone, early and middle Eocene.

***Anacolosidites sectus* Partridge, n. sp.**

(Pl. 27, figs. 7, 8)

1954 *Anacolosidites luteoides* Cookson & Pike, p. 207, Pl. 1, figs. 47-49.

DESCRIPTION: Amb triangular with convex, straight, or less commonly concave sides and moderately to narrowly rounded corners. Apertures paired, three on each polar surface, those on one surface directly overlie those on the opposite surface, apertural margins usually indistinct. Aperture in nexine slit-like, narrow, may extend to the poles and never cross the equator; apertures in sexine less distinct, margins towards the poles frequently arcuate owing to apparent sexinal thickening in the polar areas. Exine from slightly over $1\ \mu$ to $2\ \mu$ thick, sexine thinner than nexine, latter less than $0.5\ \mu$ to $1\ \mu$ thick. Columellae very small, usually not discernible except in inter-radial areas. Sexine finely perforate except in the darker, triangular to circular patch over the polar areas. Diameter 18 (21) $24\ \mu$, 18 specimens measured.

COMPARISON: *Anacolosidites sectus* differs from other species of *Anacolosidites* by having slit-like apertures.

HOLOTYPE: Specimen on slide P29744, $18\ \mu$ in diameter.

TYPE LOCALITY AND STRATA: Alberton West-138 bore at 188 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone, late Eocene.

Stephanoporate Pollen**Genus *Australopollis* Krutzsch 1966*****Australopollis obscurus* (Harris) Krutzsch 1966**

(not illustrated)

1965 *Stephanoporepollenites obscurus* Harris, p. 95, Pl. 29, figs. 15-17.

1966 *Australopollis obscurus* (Harris), Krutzsch, p. 38.

1973 ——— (Harris) Krutzsch, Stover & Evans (in press).

DESCRIPTION (Revised): Amb circular or nearly so; exine 2 to 2.5 μ thick, clearly differentiated into nexine and sexine with both layers about equally thick. Columellae singular, connected distally to form muri of small mesh reticulum; lumina generally wider than muri, polygonal to elongate. Apertures porate, equatorial to subequatorial, 5 to 7, more or less circular, 6 to 8 μ in diameter, margins ragged and pores on some specimens covered by sexinous membrane. Diameter 25 (34) 40 μ , 20 specimens measured.

STRATIGRAPHIC RANGE: *Tricolpites longus* and *Lygistepollenites balmei* Zones, Palaeocene. In the Otway Basin *Australopollis obscurus* has a longer range inasmuch as Dettmann and Playford (1969) reported this species from the *Appendicisporites distocarinatus* Zone (Cenomanian) and younger Late Cretaceous zones and Harris (1965) listed it from the early Eocene Dilwyn Clay.

REMARKS: Harris (1965) interpreted the sexine of *Australopollis obscurus* as scabrate to finely granular, whereas Krutzsch (1966) described it as punctate. By using oil immersion objectives and focusing on the outer surface of the pollen, a reticulate pattern is quite discernible. At a slightly lower focus level, that is, beneath the muri, the columellae appear as individual rodlets and impart to the pollen a granulate to scabrate appearance. On some specimens, the sculpturing is smaller on one hemisphere, and on such specimens the sexinal pattern could reasonably be interpreted as finely punctate or reticulo-punctate.

Genus *Haloragacidites* Couper 1953

Haloragacidites haloragoides Cookson & Pike 1954

(Pl. 27, figs. 4, 5)

1954 *Haloragacidites haloragoides* Cookson & Pike, p. 202, Pl. 1, figs. 7-9.

STRATIGRAPHIC RANGE: Upper part of *Tripopollenites bellus* Zone, late Miocene.

Haloragacidites harrisii (Couper) Harris 1971
(not illustrated)

1971 *Haloragacidites harrisii* (Couper) Harris in Mildenhall & Harris, pp. 304, 305, figs. 8-11. For synonymy prior to 1971 consult this reference.

1973 *Triorites harrisii* Stover & Evans (in press).

STRATIGRAPHIC RANGE: *Lygistepollenites balmei* Zone through *Tripopollenites bellus* Zone, middle Paleocene through Miocene.

Haloragacidites amolus Partridge, n. sp.
(Pl. 27, figs. 2, 3)

DESCRIPTION: Pollen isopolar, oblate, amb subcircular, outline commonly distorted. Stephanoporate, usually with 4 or 5 pores, pores aspidate, elongate, rugate. Exine averages 1.5 μ in thickness between apertures and on polar areas, up to 4 μ in thickness around pores. Areas of thickened exine dome-like and about

12 μ in diameter. Exine stratification indistinct, sexine appears to be slightly thicker than nexine, pollen in tectate. Surface psilate to scabrate. Equatorial diameter, 28 (30) 35 μ , 13 specimens measured.

COMPARISON: *Haloragacidites amolus* differs from *H. haloragoides* Cookson & Pike 1954 by having a thinner exine and more protrusive apertures.

HOLOTYPE: Specimen on slide P29817, 30 μ in diameter.

TYPE LOCALITY AND STRATA: Wurruk-1 well at 202 ft, post-*Tripopollenites bellus* Zone, probably Pliocene.

STRATIGRAPHIC RANGE: Pliocene?

Genus *Helcioporites* Partridge, n. gen.

Type Species: *Helcioporites astrus* Partridge, n. sp.
here designated.

DIAGNOSIS: Pollen free, radially symmetrical, isopolar, stephanoporate, pore number variable from 4 to 8, pores with annulate thickening of the nexine, exine minutely granulate on type species. Monotypic, affinity unknown.

COMPARISON: *Helcioporites* differs from other stephanoporate form-genera by having annuli developed in the nexine around the pores.

Helcioporites astrus Partridge, n. sp.

(Pl. 26, figs. 3-5)

DESCRIPTION: Amb circular to polygonal, margin between apertures convex to concave, equatorial view biconvex; stephanoporate, pores generally aspidate, 4 to 8, commonly 5 or 6, 1.5 to 2.5 μ in diameter. Nexinal annuli 6 to 8 μ in diameter, 1.5 μ thick; exine 1 to nearly 2 μ thick, vaguely to clearly differentiated between apertures, sexine 0.5 to 1 μ thick, minutely granulate or possibly apiculate. Dimensions, 16 (20) 24 μ in diameter, 18 specimens measured.

COMPARISON: *Helcioporites astrus* differs from *Haloragacidites haloragoides* Cookson & Pike 1954 by having circular rather than colpoid apertures, more distinct exine stratification and by having the nexine thickened adjacent to the pores to form the annuli.

HOLOTYPE: Specimen on slide P29728, 21 μ in diameter.

TYPE LOCALITY AND STRATA: Willung-121 bore at 324-326 ft, Lower *Nothofagidites asperus* Zone, middle Eocene.

STRATIGRAPHIC RANGE: *Proteacidites asperopolis* Zone through the Lower *Nothofagidites asperus* Zone; early to late Eocene.

Genus *Malvacipollis* Harris 1965

Type Species: *Malvacipollis diversus* Harris 1965,
monotypic when proposed.

COMMENTS: The circumscription by Krutzsch (1966) modified the generic concept of *Malvacipollis* to include; (1) both panaperturate and stephanoperturate pollen, (2) pollen with sexinal sculptural types in addition to those specified by Harris (1965—spinulate, spinulate) and (3) specimens in which the distribution of sexinal sculpturing is localized or global. Among

the Australian species, the sculptural features are uniformly distributed and consist of conic spinules or spines; however, only one type of sculpturing occurs on individual specimens. Pan- and stephanoperturate forms are found in Gippsland Basin assemblages and the latter are by far the more abundant.

***Malvacipollis diversus* Harris 1965**

(Pl. 26, fig. 6)

1965 *Malvacipollis diversus* Harris, p. 95, Pl. 29, fig. 18, not fig. 19.

1973 ——— Stover & Evans (in press).

DESCRIPTION (Revised): Pollen oblate, stephanoperturate, amb circular. Exine stratification fairly distinct, sexine much thicker than nexine; columellae small, singular, evenly distributed, rather dense; ectosexine psilate, attenuated into conate projections whose bases are equal to or slightly wider than their heights. Apertures equatorial, porate, 5 to 8 (usually 6), circular to elliptical, nonaspidate. Dimensions, 23 (26) 31 μ in diameter exclusive of spines, 30 specimens measured out of more than 200.

STRATIGRAPHIC RANGE: Upper part of *Lygistepollenites balmei* Zone through the *Proteacidites asperopolis* Zone, late Paleocene through early Eocene. This species is usually common in the lower portion of the *Malvacipollis diversus* Zone.

REMARKS: Harris (1965) illustrated two specimens of *Malvacipollis diversus*. The holotype (his Pl. 29, fig. 18) has low, broad-based conate projections, indications of a thin columellate layer and is relatively small. The other specimens (his Pl. 29, fig. 19) has slender sharply-tipped, spinate projections and is larger than the holotype. Based on abundant specimens from the Latrobe Group, the specimens illustrated by Harris are interpreted as representing two species, *Malvacipollis diversus* (s.s.) and *Malvacipollis subtilis* Stover, n. sp.

***Malvacipollis subtilis* Stover, n. sp.**

(Pl. 26, fig. 7-9)

1965 *Malvacipollis diversus* Harris, Pl. 29, fig. 19, not fig. 18.

DESCRIPTION: Pollen stephanoperturate, oblate to subspherical, amb circular. Exine stratification distinct, nexine extremely thin, sexine 1 to 2.5 thick, columellate layer thinner than extosexine; columellae singular, dense, uniformly distributed; ectosexine psilate, surface with spinules or spines, 2 to 4 μ long, length greater than basal diameter, tips pointed, sides tapered. Apertures equatorial on most grains, occasionally with scattered global pores as well; pores circular to elliptical, non-aspidate. Dimensions, 22 (30) 34 μ in diameter exclusive of spinules or spines, 25 specimens measured.

COMPARISON: *Malvacipollis subtilis* differs from *M. diversus* by having spines or spinules rather than conate projections, and the spines tend to be more widely spaced, particularly on specimens in the upper half of the size range on which the apertures are more apparent. Although the size ranges of the two species overlap, specimens of *M. subtilis* are generally larger.

HOLOTYPE: Specimen on slide P28088, 29 μ in diameter exclusive of spines.

TYPE LOCALITY AND STRATA: Marlin-1 well at 4891 ft, Latrobe Group, *Malvacipollis diversus* Zone, early Eocene.

STRATIGRAPHIC RANGE: Upper part of *Lygistepollenites balmei* Zone through the *Triplopollenites bellus* Zone, early Eocene through late Miocene.

Periporate Pollen

Genus *Periporopollenites* Pflug & Thomson 1953

1953 *Periporopollenites* Pflug & Thomson in Thomson & Pflug, p. 111.

1960 *Liquidambarpollenites* Raatz, Potonié, p. 134.

1960 *Caryophyllidites* Couper, p. 68.

1966 *Periporopollenites* Thomson & Pflug emend. Krutzsch, p. 39

Type Species: *Periporopollenites stigmosus* Potonié, designated by Pflug & Thomson in Thomson & Pflug (1953, p. 111).

REMARKS: *Periporopollenites* is used here for periporate pollen having 10 to approximately 32 apertures, clearly stratified and comparatively thin exines (relative to the overall size of the grains), and simple pores with or without spanning membranes. The exine is puncto-granulate to finely reticulate and lacks sculptural protrusions. This diagnosis excludes small, thick-walled, multiporate forms assignable to *Chenopodipollis* Krutzsch 1966 as well as several more coarsely sculptured forms such as *Malvacipollis* Harris 1965 and the buxaceous types.

In June 1968, Dr. P. R. Evans examined the holotype of *Caryophyllidites polyoratus* Couper 1960. Based on Evans' notes and comments (Stover, pers. comm.), on the examination of the holotype of *Polyporina fragilis* Harris 1965, and on the study of numerous specimens from the Gippsland and Bass Basins provisionally identified as *P. fragilis*, the two species are considered conspecific and assignment of these forms to *Periporopollenites* as *P. polyoratus* (Couper) Stover, new combination is proposed here.

***Periporopollenites polyoratus* (Couper) Stover, n. comb.**

(Not illustrated)

1960 *Caryophyllidites polyoratus* Couper, p. 68, Pl. 10, fig. 14.

1965 *Polyporina fragilis* Harris, p. 95, Pl. 29, fig. 20, 21.

1966 *Chenopodipollis fragilis* (Harris) Krutzsch, p. 35.

1966 *Caryophyllidites polyoratus* Couper, Krutzsch, p. 40.

STRATIGRAPHIC RANGE: *Tricolporites lilliei* Zone through *Malvacipollis diversus* Zone, Late Cretaceous into the early Eocene.

***Periporopollenites demarcatus* Stover n. sp.**

(Pl. 26, figs. 10, 11)

DESCRIPTION: Subspherical, amb circular to polygonal; exine clearly stratified, nexine about 0.5 μ thick,

sexine 1 to 1.5 μ , columellae singular, dense, uniformly distributed, ectosexine scabrate to puncto-reticulate. Pores circular or nearly so, 6 to 8 μ in diameter and with or without membraneous covering, pore number 12, pore arrangement symmetrical with 6 subequatorial to equatorial pores and 3 pores in each hemisphere located about midway between equator and poles. Because of rotation, some specimens appear to have 3 sets of 4 pores each. Dimensions, 26 (29) 35 μ , 25 specimens measured.

COMPARISON: *Periporopollenites demarcatus* differs from *P. polyoratus* by having fewer and larger apertures and is generally smaller.

HOLOTYPE: Specimen on slide P28077, 32 μ in diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 3996 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: Within the *Malvacipollis diversus* Zone into the *Proteacidites tuberculatus* Zone, early Eocene into early Miocene.

***Periporopollenites vesicus* Partridge, n. sp.**
(Pl. 26, fig. 12)

DESCRIPTION: Spherical, amb circular or nearly so, outline commonly modified by folding; exine stratification generally clear but columellae usually indistinct, exine 1.5 to 3 μ , sexine 1 to 2 μ , puncto-reticulate, thicker than nexine. Pores circular, 3 to 10 μ (average 5 μ) in diameter, generally with distended (domed) faintly granular membrane across pores; pore number 14 to 25, average 17. Dimensions, 23 (35) 50 μ in diameter, 9 specimens measured.

COMPARISON: *Periporopollenites vesicus* differs from *P. demarcatus* Stover (this paper) by having a larger number of pores, generally less distinct columellae, and by being more frequently than not, greater in diameter although the size ranges of the two species overlap.

HOLOTYPE: Specimen on slide P29893, 36 μ in diameter with 20 pores.

TYPE LOCALITY AND STRATA: Loy Yang-842 bore at 483-486 ft, *Proteacidites tuberculatus* Zone, early Oligocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone into the *Proteacidites tuberculatus* Zone, middle Eocene through Oligocene.

Pollen Retained in Tetrads

Genus *Bysmapollis* Partridge, n. gen.

Type Species: *Bysmapollis emaciatus* Partridge, n. sp., here designated.

DIAGNOSIS: Porate pollen retained exclusively in tetrahedral tetrads; pores located at the distal intersections of three individual pollen, latter triporate. Sculpturing variable, gemmate and granulate on type species. Monotypic, affinity unknown.

REMARKS: *Bysmapollis* is proposed for triporate pollen in tetrads with the pores arranged as on the type species. Because of this arrangement, the pores appear

in four groups of three pores per group around the tetrad. This particular pore configuration has not been described for other tetrad genera.

***Bysmapollis emaciatus* Partridge, n. sp.**
(Pl. 28, fig. 1)

DESCRIPTION: Individual pollen in tetrahedral tetrads subspherical, amb circular, triporate; pores elliptical, 3 x 5 μ , situated at intersections of three individual pollen, pores generally obscure. Nexine 1 to 1.5 μ thick, sexine lacking on proximal surface, on distal surface consists of granulae 0.5 to 1.5 μ in diameter, of gemmae or rounded verrucae 2 to 8 μ in diameter, 2 to 4 μ in height, generally regularly spaced. Apertures usually surrounded by band of small verrucae 1.5 to 2 μ in diameter. Diameter of tetrad exclusive of sculpturing 34 (38) 45 μ ; diameter of individual pollen 25 (29) 32 μ , 8 specimens measured.

HOLOTYPE: Specimen on slide P29744, 40 μ in diameter.

TYPE LOCALITY AND STRATA: Alberton West-138 bore at 188 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through the Lower *Nothofagidites asperus* Zone, early to late Eocene.

Genus *Ericipites* Wodehouse 1933
***Ericipites crassiexinus* Harris 1972**
(not illustrated)

1972 *Ericipites crassiexinus* Harris, pp. 54, 55, figs. 15, 16.

1973 Tetrahedral tetrad, Stover & Evans (in press).

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone through the *Triporopollenites bellus* Zone, early Eocene through Miocene.

Genus *Gephyrapollenites* Stover, n. gen.

Type Species: *Gephyrapollenites cranwellae* Stover, n. sp., here designated.

DIAGNOSIS: Monoporate pollen, free or united in tetrads; exine stratified, sexine thicker than nexine, sexine reticulate, reduced or absent proximally; pore distal, circular to elliptical, annulate.

COMPARISON: The new genus differs from *Graminidites* Cookson 1947 by having a thicker exine and a reticulate sexine at least over part of the pollen; the latter feature also serves to separate *Gephyrapollenites* from *Aglaoreidia* Erdtman 1960 on which the reticulation is not confined to the distal surface.

REMARKS: *Gephyrapollenites* is proposed for the reception of fossil pollen, either singularly or in tetrads, that are morphologically similar to the pollen from the extant genus *Drimys*.

***Gephyrapollenites cranwellae* Stover, n. sp.**
(Pl. 28, fig. 7)

DESCRIPTION: Pollen monaperturate, free or united in tetrads; equatorial outline circular or nearly so, pollen in tetrads oblate, anisopolar. Exine strati-

fication distinct; nexine thinner than sexine over equatorial and most of distal areas, apparently thicker than sexine in proximal area; sexine clearly evident distally and equatorially on isolated pollen and on those in tetrads, greatly reduced or absent proximally. Columellate layer distinct, discontinuous; columellae support muri of wide-mesh reticulum, absent in lumen. Maximum thickness of exine about $4\ \mu$; nexine approximately $1\ \mu$ thick; ectosexine thicker than endosexine. Distal polar pore circular to elliptical, $6\text{--}7\ \mu$ in diameter; nexine thickened to slightly over $2\ \mu$ around pore to form annulus; annulus about $2\ \mu$ wide. Sexine extends to pore margin or may be absent around the aperture leaving an unsculptured circular band 2 to $3\ \mu$ wide. Tetrads 43 (48) $51\ \mu$ in diameter; individual pollen 29 (31) $36\ \mu$ in diameter, 11 specimens measured.

COMPARISON: *Gephyrapollenites cranwellae* differs from other species of fossil monoporate genera by having a reticulate sexine that is strongly developed equatorially and distally.

HOLOTYPE: Specimen on slide P28077, tetrad $42 \times 49\ \mu$, individual pollen 31 to $33\ \mu$ in diameter.

TYPE LOCALITY AND STRATA: Bass-2 well at 3996 ft, Lower *Nothofagidites asperus* Zone, middle Eocene.

STRATIGRAPHIC RANGE: *Malvacipollis diversus* Zone, through *Nothofagidites asperus* Zone, early to late Eocene.

***Gephyrapollenites calathus* Partridge, n. sp.**
(Pl. 28, fig. 3)

1960 (?) *Pseudowinteria* sp. in Couper, p. 46, Pl. 5, fig. 4.

DESCRIPTION: Pollen retained in tetrahedral tetrads, individual pollen oblate, amb circular or nearly so, monoporate. Pore circular, distal, 7 to $14\ \mu$ in diameter. Exine 2 to $4\ \mu$ thick distally, less than $1\ \mu$ thick proximally where the sexine is absent; sexine on distal surface only, 1 to $3.5\ \mu$ thick, reticulate. Muri about $1\ \mu$ wide, underlain by single columellae, lumina regular to labyrinthine, up to $4\ \mu$ in diameter. Dimensions, diameter of tetrad 21 (28) $38\ \mu$, equatorial diameter of individual pollen 15 to $30\ \mu$, 10 specimens measured.

COMPARISON: *Gephyrapollenites calathus* differs from *G. cranwellae* Stover (this paper) by being smaller and by having non-annulate pores.

HOLOTYPE: Tetrad on slide P29832, $28\ \mu$ in diameter, equatorial diameter of individual pollen $22\ \mu$, polar diameter $13\ \mu$.

TYPE LOCALITY AND STRATA: Wurruk-1 well at 529 ft, *Triporopollenites bellus* Zone, late Miocene.

STRATIGRAPHIC RANGE: Lower *Nothofagidites asperus* Zone through the *Triporopollenites bellus* Zone, late Eocene through Miocene.

***Gephyrapollenites wahooensis* Stover, n. sp.**
(Pl. 28, figs. 4-6)

DESCRIPTION: Pollen retained in oblique tetrads, individual pollen pyramidal, distal surface convex

generally with slight central depression, amb roundly triangular. Exine from about $1\ \mu$ to $3\ \mu$ thick, nexine 0.5 to $1\ \mu$ thick, sexine 1.5 to $2\ \mu$ thick, reticulate distally and equatorially, sexine absent or very thin and non-reticulate proximally. Muri or reticulum about $1\ \mu$ wide or less, lumina irregular, tend to be elongate and arranged somewhat radially around the aperture, obscure and poorly defined. Dimensions, diameter of tetrad 26 (28) $31\ \mu$, equatorial diameter of individual pollen 19 (22) $24\ \mu$, polar diameter 13 to $14\ \mu$, 8 specimens measured.

COMPARISON: *Gephyrapollenites wahooensis* differs from *G. calathus* Partridge (this paper) by having a less distinct pore. There is also a marked disparity in the stratigraphic ranges of the two species.

HOLOTYPE: Specimen on slide P28101, $28\ \mu$ in diameter.

TYPE LOCALITY AND STRATA: Wahoo-1 well at 1844 ft, Latrobe Group, *Tricolpites longus* Zone, early, possibly middle Paleocene.

STRATIGRAPHIC RANGE: *Tricolporites lilliei* Zone into the *Lygistepollenites balmei* Zone, Late Cretaceous to late Paleocene.

Genus *Paripollis* Partridge, n. gen.

Type species: *Paripollis ochesis* Partridge, n. sp., here designated.

DIAGNOSIS: Pollen retained in tetrahedral tetrads, individual pollen tricolporate, apertures directly opposite each other along and at the centre of the line of contact between adjacent pollen. Sculpturing variable, verrucate on type species. Monotypic.

COMPARISON: The presence of tricolporate apertures serves to differentiate this genus from *Bysmapollis* Partridge (this paper) and from *Simplicipollis* Harris 1965 which have porate apertures, and from *Eriopites* Wodehouse 1933 which, if tricolporate rather than tricolpate, the ora are barely discernible. *Paripollis* may prove to be synonymous to *Dicotetradietes* Couper 1953. However, the precise morphology of the apertures on the latter is uncertain.

***Paripollis ochesis* Partridge, n. sp.**
(Pl. 28, fig. 2)

DESCRIPTION: Pollen retained in tetrahedral tetrads, individual pollen oblate, amb subcircular to subtriangular. Fossaperturate, colporate, ora distinct, colpi faint. Nexine 1 to $2\ \mu$ thick, sexine composed of circular to subangular verrucae with granulae between verrucae, latter 2 to $9\ \mu$ in diameter, average 2 to $3\ \mu$, 2.5 to $4\ \mu$ high and closely or widely spaced. Dimensions, tetrad diameter 33 (38) $47\ \mu$, individual pollen 23 (27) $33\ \mu$ in equatorial diameter, 8 specimens measured.

COMPARISON: The position of the apertures plus the fact that the apertures are colporate rather than porate differentiate *Paripollis ochesis* from the superficially similar *Bysmapollis emaciatius* Partridge (this paper).

HOLOTYPE: Tetrad on slide P29771, $47\ \mu$ in diameter, individual pollen $33\ \mu$ in equatorial diameter.

TYPE LOCALITY AND STRATA: Glencoe-4 well at 340 ft, Lower *Nothofagidites asperus* Zone, late Eocene.

STRATIGRAPHIC RANGE: Within the Lower *Nothofagidites asperus* Zone into the *Proteacidites tuberculatus* Zone, late Eocene and early Oligocene.

Genus *Simplicepollis* Harris 1965
Simplicepollis meridianus Harris 1965
 (not illustrated)

1965 *Simplicepollis meridianus* Harris, p. 95, Pl. 27, figs. 32, 33.

DESCRIPTION (Revised): Pollen united in tetrahedral tetrads; distal surface of individual pollen hemispherical, proximal surface pyramidal. Exine stratification distinct, nexine about $0.5\ \mu$ thick, sexine about $1\ \mu$ thick, composed of dense, evenly distributed, minute columellae. In areas where adjacent pollen are in contact, the columellae form an imperfect intervening layer. Pollen triporate, pores broadly elliptical, about $6 \times 4\ \mu$; aperture commonly spanned by thin membrane with scattered granulae. Equatorial diameter of individual pollen 17 to $33\ \mu$, of tetrads 31 to $42\ \mu$.

STRATIGRAPHIC RANGE: Within the *Tricolporites lilliei* Zone through the Lower *Nothofagidites asperus* Zone, Late Cretaceous into late Eocene.

REMARKS: Occasional specimens with 4 or 5 pores per individual pollen have been observed in assemblages from the Lower *Nothofagidites asperus* Zone. On such specimens, the pores are on the distal surface only and slightly off the equator. In general, specimens at the smaller end of the size range are found in assemblages from the older zones, whereas those at the larger end occur most frequently in the younger zones.

Genus *Quadrplanus* Stover, n. gen.
 Type Species: *Quadrplanus brossus* Stover, n. sp., here designated.

DIAGNOSIS: Pollen united in obligate planar (square) tetrads; individual pollen without radial symmetry and with an equatorial plane of symmetry. Apertures usually indistinct, individual pollen tetraporate, pores arranged in pairs on opposite polar surfaces (as in *Anacolosidites*) pairs at distal, subequatorial areas adjacent to the junctions of the individual pollen. Sexual sculpturing variable, baculate to clavate on the type species. Monotypic.

REMARKS: This form genus is proposed for pollen retained in obligate planar (square) tetrads. No other form genus has been proposed for tetrads with this configuration.

Quadrplanus brossus Stover, n. sp.
 (Pl. 27, figs. 12-15)

DESCRIPTION: Pollen united in obligate planar (square) tetrads, circular in polar view, oblate to sub-spherical with flattened polar surfaces in equatorial view. Individual pollen occasionally fail to meet at the centre of the tetrad. Pollen within the tetrad isopolar, somewhat subtriangular in polar view, tetraporate;

pores in nexine only, paired (as in *Anacolosidites*), two pairs per individual pollen. Pores occur near the distal corners of the pollen adjacent to the junctions of the individual pollen. Exine at the equator of the tetrad 4 to $6\ \mu$ thick, including sculpturing, nexine 1 to $2\ \mu$ thick, thickest around the pores and over the distal surfaces, thinner elsewhere. Sexine baculate and clavate, larger features tend to be clavae. A layer, less than $1\ \mu$ thick at the base of the sexine appears to bind the bases of the baculae or clavae. Baculae and clavae not connected distally and extend across the pores.

The sculptural features average 1 to $2\ \mu$ in diameter over most of the individual pollen, may be up to 5 microns in diameter and $3\ \mu$ in height, largest tend to occur along the junctions of individual pollen and the smallest in the polar areas. Dimensions, equatorial diameter 36 (46) $60\ \mu$, 12 specimens measured.

HOLOTYPE: Specimen on slide P28101, $40\ \mu$ in diameter.

TYPE LOCALITY AND STRATA: Wahoo-1 well at 1844 ft, *Tricolpites longus* Zone, early Paleocene, possibly middle Paleocene.

STRATIGRAPHIC RANGE: Within *Tricolporites lilliei* Zone through the *Tricolpites longus* Zone, Late Cretaceous to early Paleocene, possibly middle Paleocene.

Genus *Polyadopollenites* Pflug 1953
Polyadopollenites myriosporites (Cookson) Partridge, n. comb.
 (Pl. 27, fig. 11)

1954 *Acacia myriosporites* Cookson, p. 55, Pl. 1, figs. 1, 5-8.

DESCRIPTION (Revised): Radially symmetrical polyad of 16 pollen, peroblate, circular to broadly elliptical in outline. Outline of individual pollen polar area square (13 to $15\ \mu$), in equatorial area rectangular ($8 \times 12\ \mu$ to $10 \times 16\ \mu$), distal surface of individual pollen with faint, polygonal colpi. Exine less than $1\ \mu$, psilate, nexine thicker than sexine, irregular patches of suprategillar granulae, $0.5\ \mu$ in diameter, on some polyads. Dimensions, 30 to $44\ \mu \times 40$ to $47\ \mu$, 5 specimens measured.

LECTOTYPE: Specimen on slide P29898, $52 \times 52\ \mu$, and illustrated by Cookson (1954, Pl. 1, fig. 1).

TYPE LOCALITY AND STRATA: North bank of Grange Burn near Hamilton, Victoria; carbonaceous clay below diatomite, ? late Pliocene.

STRATIGRAPHIC RANGE: Within *Proteacidites tuberculatus* Zone through the *Triporopollenites bellus* Zone, Miocene.

Inaperturate Pollen

Genus *Dilwynites* Harris 1965
Dilwynites granulatus Harris 1965
 (not illustrated)

1965 *Dilwynites granulatus* Harris, p. 88, Pl. 27, figs. 6, 7.

STRATIGRAPHIC RANGE: Within the *Tricolpites longus* Zone through the *Triporopollenites bellus* Zone, Paleocene through Miocene.

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APPENDIX 1

REGISTER OF LOCALITIES

1. Alberton West-138, Lat. 38° 38'S, Long. 146° 33'E, sample from 188 ft.
2. Barracouta-1, Lat. 38° 16' 41"S, Long. 147° 42' 45"E, samples from (a) 7251 ft and (b) 8695 ft.
3. Bass-1, Lat. 39° 46' 18"S, Long. 145° 44' 03"E, sample from 5400 ft.
4. Bass-2, Lat. 39° 53' 09"S, Long. 146° 18' 18"E, samples from (a) 3822 ft, (b) 3996 ft, (c) 4308 ft, (d) 4573 ft, (e) 4648 ft, (f) 4937 ft and (g) 5508 ft.
5. Colquhoun-12, Lat. 37° 23'S, Long. 147° 59'E, sample from 1352-1363 ft.
6. Coolungoolun-1, Lat. 38° 13'S, Long. 147° 04'E, sample from 290 ft.
7. Glencoe-4, Lat. 38° 11'S, Long. 147° 05'E, samples from (a) 280 ft, and (b) 340 ft.
8. Lakes Entrance Oil Shaft, Parish of Colquhoun, Allotment 31, East Gippsland, samples from (a) 352 ft, (b) 416 ft, (c) 492 ft and (d) 1188 ft.
9. Loy Yang-842, Lat. 38° 15'S, Long. 146° 37'E, samples from (a) 290-295 ft and (b) 483-486 ft.
10. Marlin-1, Lat. 38° 14' 03"S, Long. 148° 15' 33"E, sample from 4891 ft.
11. Marlin-2, Lat. 38° 15' 59"S, Long. 148° 10' 45"E, samples from (a) 7402 ft and (b) 8121 ft.

12. Marlin-3, Lat. 38° 14' 44"S, Long. 148° 10' 16"E, samples from (a) 5070 ft, (b) 5088 ft and (c) 5127 ft.
13. Maryvale-155, Lat. 38° 15'S, Long. 146° 24'E, sample from 552 ft.
14. Moolamoon Coal Mine, co-ordinates from Mirboo North Geologic Map; E 412.290, N 275.839, samples from (a) coal directly below basalt and (b) clay above coal further south.
15. Morwell Open Cut, Morwell, Victoria, sample from clay split between Morwell 1A and 1B seams, north wall approximately 200 ft above base of Morwell 1B seam.
16. Rosedale-1, Lat. 38° 08'S, Long. 146° 47'E, samples from (a) 476-480 ft, (b) 876-878 ft, (c) 1854-1857 ft, (d) 2098-2100 ft and (e) 2287-2289 ft.
17. Snapper-2, Lat. 38° 11' 16"S, Long. 148° 02' 37"E, sample from 8194 ft.
18. Tuna-1, Lat. 38° 10' 25"S, Long. 148° 25' 03"E, samples from (a) 4315-4317 ft and (b) 5927 ft.
19. Wahoo-1, Lat. 38° 01' 42"S, Long. 148° 44' 48"E, samples from (a) 1844 ft and (b) 1890 ft.
20. Willung-121, Lat. 38° 18'S, Long. 146° 44'E, samples from (a) 246-248 ft, and (b) 324-326 ft.
21. Wurruk-1, Lat. 38° 05'S, Long. 147° 02'E, samples from (a) 202 ft, (b) 426 ft, (c) 529 ft, (d) 716 ft, (e) 2698 ft, (f) 2898 ft and (g) 3023 ft.
22. Yallourn Open Cut, Yallourn, Victoria, samples from (a) clay at floor of cut below Yallourn seam, and (b) Yallourn seam approximately 80 ft above floor at north end.
23. Yallourn North Extension Open Cut, sample from Latrobe seam at base of lowest batter.

APPENDIX 2

REGISTER OF ILLUSTRATED SPECIMENS

| SLIDE | LOCALITY | SPECIES | TYPE | PL. | FIG. | CO-ORDINATES |
|---------|----------|--------------------------------------|----------|-----|------|---------------|
| P 28048 | 11 (a) | <i>Proteacidites angulatus</i> | paratype | 22 | 5 | R 02.0 + 12.5 |
| P 28049 | 4 (c) | <i>Banksiaeidites arcuatus</i> | holotype | 21 | 2 | L 01.6 + 13.7 |
| | | <i>Dryptopollenites semilunatus</i> | holotype | 17 | 1 | R 06.3 + 15.0 |
| | | <i>D. semilunatus</i> | paratype | 17 | 2 | R 04.8 + 17.3 |
| | | <i>Proteacidites asperopolus</i> | topotype | 26 | 2 | L 16.5 + 08.2 |
| | | <i>P. beddoesii</i> | holotype | 22 | 3 | R 02.8 + 13.0 |
| | | <i>P. beddoesii</i> | paratype | 22 | 4 | R 03.6 + 02.3 |
| | | <i>P. leightonii</i> | holotype | 23 | 1 | L 03.6 + 08.0 |
| | | <i>P. leightonii</i> | paratype | 23 | 2 | R 06.1 + 02.8 |
| | | <i>Tricolpites incisus</i> | holotype | 17 | 4 | R 02.8 + 13.0 |
| | | <i>T. incisus</i> | paratype | 17 | 5 | R 03.8 + 19.0 |
| | | <i>Triporopollenites ambiguus</i> | holotype | 21 | 7 | L 02.0 + 12.3 |
| P 28050 | 4 (e) | <i>Baculatisporites disconformis</i> | holotype | 13 | 8 | R 04.0 + 01.8 |
| | | <i>Liliacidites lanceolatus</i> | holotype | 16 | 9 | R 08.6 + 05.0 |
| | | <i>L. lanceolatus</i> | paratype | 16 | 10 | R 04.4 + 09.3 |
| | | <i>Malvacipollis diversus</i> | hypotype | 26 | 6 | R 09.0 - 01.1 |
| | | <i>M. subtilis</i> | paratype | 26 | 8 | L 17.8 + 05.4 |
| | | <i>Proteacidites adenantoides</i> | hypotype | 22 | 8 | L 09.9 + 12.1 |
| | | <i>Rugulatisporites mallatus</i> | holotype | 15 | 1 | R 07.1 + 05.5 |
| | | <i>Tricolporites paenestriatus</i> | holotype | 19 | 1 | L 21.6 + 11.1 |
| P 28055 | 4 (f) | <i>Polycolpites langstonii</i> | holotype | 20 | 12 | R 08.6 + 12.3 |
| P 28057 | 3 | <i>Ischyosporites gremius</i> | holotype | 14 | 8 | L 05.7 + 09.0 |
| P 28063 | 4 (g) | <i>Gambierina rudata</i> | holotype | 21 | 8 | L 11.2 + 06.5 |
| P 28065 | 12 (a) | <i>Bombacacidites bombaxoides</i> | hypotype | 19 | 3 | R 09.7 + 15.8 |
| | | <i>Malvacipollis subtilis</i> | paratype | 26 | 7 | R 05.8 + 00.4 |
| P 28066 | 4 (b) | <i>Gothanipollis bassensis</i> | holotype | 17 | 13 | L 20.4 + 15.5 |
| | | <i>Liliacidites bainii</i> | paratype | 16 | 7 | R 00.2 + 06.5 |
| | | <i>Polycolpites esobalteus</i> | hypotype | 20 | 11 | R 03.3 + 10.5 |
| | | <i>Tricolpites phillipsii</i> | holotype | 17 | 6 | R 02.4 + 01.1 |
| | | <i>T. phillipsii</i> | paratype | 17 | 7 | L 07.2 + 14.3 |
| P 28071 | 4 (a) | <i>Proteacidites obscurus</i> | hypotype | 25 | 4 | L 08.0 + 04.9 |
| P 28074 | 12 (c) | <i>Banksiaeidites arcuatus</i> | paratype | 21 | 3 | L 04.1 + 00.2 |
| | | <i>Polycolpites esobalteus</i> | hypotype | 20 | 10 | R 05.0 + 16.7 |
| | | <i>Proteacidites pseudonoides</i> | holotype | 25 | 3 | L 01.4 + 05.0 |
| P 28076 | 12 (b) | <i>P. alveolatus</i> | holotype | 22 | 1 | L 16.4 + 05.5 |

| SLIDE | LOCALITY | SPECIES | TYPE | PL. | FIG. | CO-ORDINATES |
|---------|----------|--------------------------------------|----------|-----|------|---------------|
| | | <i>P. alveolatus</i> | paratype | 22 | 2 | L 09.3 + 04.2 |
| P 28077 | 4 (b) | <i>Gephyrapollenites cranwellae</i> | holotype | 28 | 7 | R 06.2 + 11.6 |
| | | <i>Periporopollenites demarcatus</i> | holotype | 26 | 11 | L 08.0 + 01.0 |
| P 28078 | 10 | <i>Proteacidites tenuixinus</i> | paratype | 25 | 6 | L 06.3 + 06.0 |
| P 28079 | 10 | <i>Schizocolpus marlinensis</i> | holotype | 18 | 3 | L 01.6 + 11.7 |
| P 28082 | 11 (b) | <i>Tetracolporites verrucosus</i> | holotype | 20 | 2 | L 08.0 + 03.3 |
| P 28085 | 4 (b) | <i>Proteacidites tenuixinus</i> | holotype | 25 | 7 | L 20.5 + 17.6 |
| P 28088 | 10 | <i>Malvacipollis subtilis</i> | holotype | 26 | 9 | R 00.6 + 10.5 |
| P 28090 | 4 (d) | <i>Schizocolpus marlinensis</i> | paratype | 18 | 4 | R 10.3 + 13.7 |
| P 28091 | 2 (a) | <i>Proteacidites angulatus</i> | holotype | 22 | 6 | L 15.0 + 10.2 |
| P 28093 | 2 (b) | <i>Triporopollenites sectilis</i> | holotype | 21 | 5 | L 01.3 + 12.2 |
| P 28095 | 4 (b) | <i>Liliacidites bainii</i> | holotype | 16 | 8 | L 06.3 + 02.1 |
| P 28097 | 18 (b) | <i>Tricolpites confessus</i> | holotype | 17 | 3 | L 02.8 + 11.4 |
| P 28101 | 19 (a) | <i>Gephyrapollenites wahooensis</i> | holotype | 28 | 4 | L 20.1 + 02.1 |
| | | <i>Quadruplanus brossus</i> | holotype | 27 | 13 | L 22.0 + 08.2 |
| | | <i>Q. brossus</i> | paratype | 27 | 14 | L 20.5 + 08.1 |
| P 28102 | 19 (a) | <i>Gephyrapollenites wahooensis</i> | paratype | 28 | 6 | R 05.2 + 09.4 |
| P 28103 | 19 (b) | <i>G. wahooensis</i> | paratype | 28 | 5 | L 03.3 + 00.1 |
| P 28118 | 17 | <i>Tetracolporites verrucosus</i> | paratype | 20 | 1 | L 05.2 + 06.0 |
| P 29712 | 15 | <i>Proteacidites tuberculatus</i> | hypotype | 24 | 1 | R 05.5 + 05.0 |
| P 29713 | 15 | <i>Cyathidites subtilis</i> | paratype | 13 | 2 | R 12.2 + 06.5 |
| P 29714 | 8 (a) | <i>C. subtilis</i> | holotype | 13 | 1 | R 02.5 + 14.2 |
| P 29717 | 14 (b) | <i>Tricolporites retequetrus</i> | paratype | 19 | 9 | R 07.3 + 05.3 |
| P 29720 | 15 | <i>Matonisporites ornamentalis</i> | hypotype | 13 | 3 | L 07.4 + 11.5 |
| | | <i>Proteacidites rectomarginis</i> | hypotype | 23 | 6 | L 08.0 + 03.2 |
| | | <i>Psilastephanocolporites micus</i> | paratype | 20 | 5 | L 14.1 + 12.8 |
| P 29721 | 14 (a) | <i>Tricolporites leuros</i> | holotype | 19 | 7 | R 19.1 + 19.6 |
| P 29723 | 15 | <i>Foveotrilites crater</i> | holotype | 14 | 2 | R 07.3 + 16.6 |
| P 29724 | 15 | <i>Cyatheacidites annulatus</i> | hypotype | 13 | 6 | R 17.0 + 14.0 |
| | | <i>Proteacidites rectomarginis</i> | hypotype | 23 | 7 | R 15.8 + 01.2 |
| P 29725 | 15 | <i>Cyatheacidites annulatus</i> | hypotype | 13 | 5 | R 06.8 + 08.2 |
| | | <i>Proteacidites rectomarginis</i> | hypotype | 23 | 8 | L 04.8 + 17.2 |
| P 29728 | 20 (b) | <i>Anisotricolporites triplaxis</i> | holotype | 18 | 8 | L 07.9 + 13.2 |
| | | <i>Helciporites astrus</i> | holotype | 26 | 3 | L 05.6 + 10.5 |
| | | <i>Tricolporites scabratus</i> | hypotype | 19 | 2 | R 09.0 + 12.3 |
| P 29732 | 9 (b) | <i>Granodiporites nebulosus</i> | holotype | 21 | 1 | R 03.4 + 14.5 |
| P 29734 | 8 (d) | <i>Foveotrilites palaequetrus</i> | holotype | 14 | 4 | R 01.5 + 09.3 |
| P 29738 | 14 (b) | <i>Tricolporites leuros</i> | paratype | 19 | 6 | R 04.2 + 14.2 |
| P 29739 | 21 (f) | <i>Verrucosisporites kopukuensis</i> | hypotype | 16 | 2 | R 02.7 + 07.6 |
| P 29743 | 22 (a) | <i>Myrtacidites verrucosus</i> | holotype | 17 | 17 | L 22.3 + 11.6 |
| | | <i>Proteacidites symphyonemoides</i> | hypotype | 25 | 2 | R 05.4 + 00.6 |
| P 29744 | 1 | <i>Anacolosidites sectus</i> | holotype | 27 | 7 | L 15.3 + 12.8 |
| | | <i>A. sectus</i> | paratype | 27 | 8 | L 19.2 + 01.1 |
| | | <i>Bysmapollis emaciatus</i> | holotype | 28 | 1 | L 17.9 + 20.5 |
| P 29746 | 20 (a) | <i>Parvisaccites catastus</i> | holotype | 16 | 5 | R 09.4 + 00.3 |
| | | <i>P. catastus</i> | paratype | 16 | 6 | R 08.5 + 03.5 |
| | | <i>Periporopollenites demarcatus</i> | paratype | 26 | 10 | R 02.9 + 19.6 |
| | | <i>Proteacidites recavus</i> | paratype | 24 | 4 | L 01.7 + 18.4 |
| P 29747 | 21 (f) | <i>P. reticulatus</i> | hypotype | 23 | 5 | R 02.2 + 12.1 |
| P 29750 | 15 | <i>Matonisporites ornamentalis</i> | hypotype | 13 | 4 | L 08.7 + 08.6 |
| P 29755 | 20 (b) | <i>Tricolpites sinatus</i> | holotype | 17 | 8 | R 09.2 + 08.7 |
| P 29756 | 1 | <i>Banksiaeidites arcuatus</i> | paratype | 21 | 4 | L 16.2 + 19.2 |
| | | <i>Concolpites leptos</i> | holotype | 18 | 1 | L 14.5 + 19.2 |
| | | <i>Gothanipollis bassensis</i> | paratype | 17 | 16 | L 03.7 + 14.2 |
| P 29757 | 9 (b) | <i>Proteacidites stipplatus</i> | holotype | 24 | 3 | R 02.7 + 09.6 |
| P 29758 | 20 (b) | <i>Helciporites astrus</i> | paratype | 26 | 5 | R 03.6 + 10.1 |

| SLIDE | LOCALITY | SPECIES | TYPE | PL. | FIG. | CO-ORDINATES |
|---------|----------|---|----------|-----|------|---------------|
| P 29761 | 14 (b) | <i>Aglaoreidia qualumis</i> | paratype | 20 | 9 | R 02.0 + 16.7 |
| P 29770 | 21 (f) | <i>Tricolporites retequetrus</i> | holotype | 19 | 8 | L 08.6 + 08.8 |
| P 29771 | 7 (b) | <i>Paripollis ochesis</i> | holotype | 28 | 2 | L 17.0 + 13.3 |
| | | <i>Proteacidites latrobensis</i> | hypotype | 25 | 5 | L 22.2 + 07.0 |
| P 29774 | 21 (e) | <i>Proteacidites stipplatus</i> | paratype | 24 | 2 | R 02.4 + 09.8 |
| P 29777 | 21 (b) | <i>Foveotrilites crater</i> | paratype | 14 | 3 | R 03.4 + 14.0 |
| P 29780 | 21 (b) | <i>Polypodiaceoisporites tumulatus</i> | holotype | 16 | 4 | R 02.6 + 06.9 |
| P 29781 | 21 (b) | <i>Tripoporipollenites bellus</i> | paratype | 27 | 10 | R 08.0 + 12.7 |
| P 29784 | 7 (a) | <i>Triorites magnificus</i> | hypotype | 25 | 9 | R 01.1 + 15.0 |
| P 29792 | 21 (f) | <i>Verrucosisporites kopukuensis</i> | hypotype | 16 | 3 | R 02.5 + 11.8 |
| P 29794 | 21 (f) | <i>Rugulatisporites trophus</i> | holotype | 15 | 4 | R 07.6 + 07.3 |
| P 29795 | 7 (a) | <i>Peromonolites vellosus</i> | holotype | 16 | 1 | R 01.1 + 07.4 |
| P 29796 | 21 (b) | <i>Rugulatisporites micraulaxus</i> | holotype | 15 | 3 | L 09.0 + 02.2 |
| P 29797 | 21 (b) | <i>Haloragacidites haloragoides</i> | hypotype | 27 | 4 | R 02.0 + 17.7 |
| | | <i>Sapotaceoidaepollenites rotundus</i> | hypotype | 20 | 13 | R 02.6 + 15.4 |
| P 29798 | 21 (b) | <i>Symplocoipollenites austellus</i> | holotype | 17 | 20 | L 06.2 + 09.6 |
| P 29801 | 15 | <i>Foveotrilites crater</i> | paratype | 14 | 1 | L 05.2 + 11.3 |
| P 29803 | 20 (b) | <i>Anacolosidites luteoides</i> | hypotype | 27 | 6 | L 02.8 + 09.3 |
| | | <i>Gothanipollis bassensis</i> | paratype | 17 | 14 | L 13.8 + 02.9 |
| | | <i>G. bassensis</i> | paratype | 17 | 15 | L 01.2 + 06.7 |
| | | <i>Tricolpites simatus</i> | paratype | 17 | 10 | R 02.0 + 05.7 |
| P 29804 | 8 (d) | <i>Verrucosisporites cristatus</i> | holotype | 15 | 5 | L 01.4 + 09.3 |
| P 29805 | 16 (b) | <i>Polycolpites reticulatus</i> | hypotype | 20 | 7 | L 15.5 + 09.5 |
| P 29807 | 8 (b) | <i>Tubulifloridites antipodica</i> | hypotype | 18 | 12 | R 02.4 + 01.5 |
| P 29808 | 21 (d) | <i>T. antipodica</i> | hypotype | 18 | 11 | L 07.9 + 12.1 |
| P 29814 | 21 (b) | <i>Haloragacidites haloragoides</i> | hypotype | 27 | 5 | L 08.1 + 10.2 |
| | | <i>Polyadipollenites myriosporites</i> | hypotype | 27 | 11 | L 09.8 + 14.9 |
| P 29816 | 21 (b) | <i>Milfordia homeopunctata</i> | hypotype | 21 | 10 | R 04.6 + 06.6 |
| P 29817 | 21 (a) | <i>Haloragacidites amolousus</i> | holotype | 27 | 2 | L 03.2 + 10.4 |
| | | <i>H. amolousus</i> | paratype | 27 | 3 | L 08.2 + 10.3 |
| | | <i>Rugulatisporites micraulaxus</i> | paratype | 15 | 2 | R 04.5 + 05.2 |
| P 29821 | 7 (a) | <i>Tripoporipollenites chnosus</i> | holotype | 21 | 6 | R 02.8 + 09.8 |
| P 29825 | 7 (a) | <i>Milfordia homeopunctata</i> | hypotype | 21 | 11 | R 15.5 + 03.8 |
| P 29827 | 16 (d) | <i>Aglaoreidia qualumis</i> | holotype | 20 | 8 | R 01.4 + 13.3 |
| P 29828 | 16 (c) | <i>Foveotrilites balteus</i> | holotype | 14 | 7 | R 06.5 + 15.3 |
| P 29831 | 16 (a) | <i>Tripoporipollenites bellus</i> | holotype | 27 | 9 | L 07.4 + 09.0 |
| P 29832 | 21 (c) | <i>Gephyrapollenites calathus</i> | holotype | 28 | 3 | L 04.0 + 17.8 |
| P 29834 | 20 (b) | <i>Helcioporites astrus</i> | paratype | 26 | 4 | L 05.6 + 10.5 |
| P 29840 | 20 (b) | <i>Anisotricolporites triplaxis</i> | paratype | 18 | 9 | L 12.6 + 01.9 |
| P 29844 | 9 (b) | <i>Peromonolites vellosus</i> | paratype | 15 | 6 | L 12.1 + 08.4 |
| P 29845 | 21 (g) | <i>Tricolporites angurium</i> | holotype | 18 | 10 | L 12.6 + 04.7 |
| P 29847 | 8 (c) | <i>Foveotrilites lacunosus</i> | holotype | 14 | 6 | R 06.7 + 04.6 |
| P 29848 | 5 | <i>F. palaequetrus</i> | paratype | 14 | 5 | L 01.9 + 18.6 |
| P 29849 | 22 (b) | <i>Psilastephanocolporites micus</i> | paratype | 20 | 6 | R 00.4 + 10.9 |
| P 29850 | 22 (b) | <i>P. micus</i> | paratype | 20 | 4 | R 05.9 + 05.0 |
| P 29851 | 22 (b) | <i>P. micus</i> | holotype | 20 | 3 | R 07.4 + 08.9 |
| P 29852 | 23 | <i>Tricolporites leuros</i> | paratype | 19 | 5 | L 01.1 + 12.5 |
| P 29855 | 16 (e) | <i>Gemmatricolporites gestus</i> | holotype | 19 | 4 | R 06.1 + 14.1 |
| P 29856 | 16 (e) | <i>Proteacidites reflexus</i> | holotype | 24 | 6 | L 05.0 + 03.9 |
| P 29858 | 9 (b) | <i>Herkosporites elliottii</i> | holotype | 13 | 7 | L 01.5 + 04.3 |
| P 29860 | 6 | <i>Proteacidites recavus</i> | holotype | 24 | 5 | R 01.0 + 08.8 |
| P 29866 | 9 (a) | <i>Myrtacidites verrucosus</i> | paratype | 17 | 18 | L 22.3 + 15.7 |
| P 29874 | 13 | <i>Tricolporites sphaerica</i> | topotype | 18 | 6 | R 03.5 + 11.7 |
| P 29875 | 13 | <i>T. sphaerica</i> | neotype | 18 | 5 | R 03.0 + 06.7 |
| P 29876 | 13 | <i>T. sphaerica</i> | topotype | 18 | 7 | L 00.9 + 12.3 |
| P 29885 | 20 (b) | <i>Tricolpites simatus</i> | paratype | 17 | 9 | R 11.4 + 19.5 |

| SLIDE | LOCALITY | SPECIES | TYPE | PL. | FIG. | CO-ORDINATES |
|---------|----------|-----------------------------------|----------|-----|------|---------------|
| P 29888 | 14 (a) | <i>Myrtaceidites verrucosus</i> | paratype | 17 | 19 | L 08.8 + 00.8 |
| P 29889 | 20 (b) | <i>Tricolpites simatus</i> | paratype | 17 | 11 | L 03.3 + 11.5 |
| P 29893 | 9 (b) | <i>Periporopollenites vesicus</i> | holotype | 26 | 12 | L 00.9 + 04.1 |
| P 29900 | 18 (a) | <i>Concolpites leptos</i> | paratype | 18 | 2 | L 07.9 + 03.3 |
| P 29901 | 19 (a) | <i>Quadruplanus brossus</i> | paratype | 27 | 12 | R 04.2 - 01.0 |
| | | <i>Q. brossus</i> | paratype | 27 | 15 | R 02.7 + 10.2 |

SLIDES FROM DR I. C. COOKSON'S COLLECTION

| | | | | | |
|---------|------------------------------------|-----------|----|----|---------------|
| P 29660 | <i>Tricolpites thomasi</i> | lectotype | 17 | 12 | R 07.2 + 13.5 |
| P 29661 | <i>Anacolosidites acutullus</i> | lectotype | 27 | 1 | L 01.6 + 10.5 |
| P 29664 | <i>Gambierina edwardsii</i> | lectotype | 21 | 9 | L 05.8 + 11.1 |
| P 29669 | <i>Proteacidites adenanthoides</i> | lectotype | 22 | 7 | R 24.2 + 5.0 |
| | <i>P. grandis</i> | lectotype | 23 | 3 | L 01.6 + 15.2 |
| P 29670 | <i>P. symphyonemoides</i> | lectotype | 25 | 1 | L 05.4 + 05.2 |
| P 29678 | <i>P. pachypolus</i> | lectotype | 26 | 1 | L 02.6 + 16.4 |
| P 29693 | <i>P. incurvatus</i> | lectotype | 25 | 8 | R 19.8 + 12.0 |
| P 29695 | <i>P. crassus</i> | lectotype | 22 | 9 | R 25.4 + 03.9 |
| | <i>P. reticulatus</i> | neotype | 23 | 4 | R 30.2 + 17.8 |

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EXPLANATION OF PLATES

Specimens photographed in normal transmitted light and enlarged to 800 magnification unless stated otherwise.

PLATE 13

- FIG. 1, 2—*Cyathidites subtilis* n. sp. Figs. 1a, 1b, proximal and distal surfaces of holotype; Fig. 2, paratype at intermediate focus level.
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- FIG. 1-3—*Foveotrilites crater* n. sp. Figs. 1a-1c, proximal, equatorial and distal focus levels of paratype. Figs. 2a-2c, same as above for holotype. Figs. 3a-3c, same as above for another paratype.
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 FIG. 6—*Foveotrilites lacunosus* n. sp. Figs. 6a-6c, proximal, equatorial and distal focus levels of holotype, $\times 750$.
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- FIG. 1—*Rugulatisporites mallatus* n. sp. Figs. 1a, 1b, proximal surface of holotype at two focus levels; 1c, intermediate focus level showing outline of rugulae.
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 FIG. 6—*Peromonolites vellosus* n. sp. Paratype at intermediate focus level.

PLATE 16

- FIG. 1—*Peromonolites vellosus* n. sp. Figs. 1a, 1b, oblique view of holotype at proximal and intermediate focus levels.
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PLATE 17

- FIG. 1, 2—*Dryptopollenites semilunatus* n. gen., n. sp. Figs. 1a, 1b, holotype at two focus levels. Fig. 2, paratype.
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 FIG. 12—*Tricolpites thomasi* Cookson & Pike 1954. Figs. 12a-12c, lectotype at three focus levels.

- FIG. 13-16—*Gothanipollis bassensis* n. sp. Figs. 13a, holotype; 13b, same in phase contrast. Figs 14-16, paratypes.
 FIG. 17-19—*Myrtaceidites verrucosus* n. sp. Figs. 17a, 17b, holotypes at two focus levels. Figs. 18, 19, paratypes.
 FIG. 20—*Symplocoipollenites austellus* n. sp. Figs. 20a, 20b, holotype at two focus levels.

PLATE 18

- FIG. 1, 2—*Concolpites leptos* n. gen., n. sp. Figs. 1a-1c, holotype at consecutive focus levels. Fig. 2, paratype.
 FIG. 3, 4—*Schizocolpus marlinensis* n. gen., n. sp. Figs. 3a, 3b, holotype at high and intermediate focus levels; 3c, 3d, same in phase contrast. Figs. 4a, 4e, paratype shown at opposite polar surfaces; 4b-4d, same at consecutive focus levels in phase contrast, note ora at ends of colpi.
 FIG. 5-7—*Tricolporites sphaerica* Cookson 1947. Figs. 5a-5e, neotype at consecutive focus levels. Figs. 6a-6c, topotype at three focus levels. Figs. 7a, 7b, another topotype in polar view at high and intermediate focus levels.
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 FIG. 10—*Tricolporites angurium* n. sp. Figs. 10b-10d, holotype at three focus levels; 10a, portion of reticulation in phase contrast.
 FIG. 11, 12—*Tubulifloridites antipodica* Cookson 1947. Fig. 11, equatorial view of hypotype. Figs. 12a, 12b, polar view of another hypotype at two focus levels.

PLATE 19

- FIG. 1—*Tricolporites paenestriatus* n. sp. Figs. 1a, 1b, holotype at two focus levels; 1c, same in phase contrast.
 FIG. 2—*Tricolporites scabratus* Harris 1965. Figs. 2a, 2b, hypotype in phase contrast; 2c, same at intermediate focus level.
 FIG. 3—*Bombacacidites bombaxoides* Couper 1960. Hypotype.
 FIG. 4—*Gemmatricolporites gestus* n. sp. Fig. 4a, polar surface of holotype; 4b, 4c, same in interference contrast at two focus levels, $\times 500$.
 FIG. 5-7—*Tricolporites leuros* n. sp. Figs. 5a, 5b, paratype at high and intermediate focus levels. Figs. 6a, 6b, another paratype in equatorial view showing apertures. Figs. 7a, 7b, holotype at high and intermediate focus levels.
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- FIG. 1, 2—*Tetracolporites verrucosus* n. sp. Figs. 1a, 1b, polar view of paratype. Figs. 2a, 2b, opposite surfaces of holotype.
 FIG. 3-6—*Psilastephanocolporites micus* n. sp. Figs. 3a-3c, three focus levels of holotype from pole to equator. Figs. 4a, 4b, equatorial view of holotype. Figs. 5a, 5b, polar surface of another paratype in phase contrast; 5c, same specimen, focus near equator. Fig. 6, another paratype.
 FIG. 7—*Polycolpites reticulatus* Couper 1960. Fig. 7a, hypotype; 7b, same in phase contrast.
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 FIG. 12—*Polycolpites langstonii* n. sp. Figs. 12a, 12b, holotype at two focus levels.
 FIG. 13—*Sapotaceodaepollenites rotundus* Harris 1972. Figs. 13a, 13b, hypotype, equatorial view.

PLATE 21

- FIG. 1—*Granodiporites nebulosus* n. sp. Figs. 1b, 1c, holotype at high and intermediate focus levels; 1a, portion of surface in phase contrast.
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 FIG. 6—*Triporopollenites chnosus* n. sp. Figs. 6a, 6b, holotype at high and intermediate focus levels.
 FIG. 7—*Triporopollenites ambiguus* n. sp. Figs. 7a, 7b, holotype at high and intermediate focus levels.
 FIG. 8—*Gambierina rudata* n. sp. Figs. 8a, 8b, holotype at high and intermediate focus levels.
 FIG. 9—*Gambierina edwardsii* (Cookson & Pike) Harris 1972. Lectotype.
 FIG. 10, 11—*Milfordia homeopunctata* (McIntyre) n. comb. Fig. 10, hypotype, ulcate specimen. Fig. 11, another hypotype, porate specimen.

PLATE 22

- FIG. 1, 2—*Proteacidites alveolatus* n. sp. Figs. 1a, 1b, holotype at high and intermediate focus levels; 1c, same in interference contrast. Fig. 2, paratype.
- FIG. 3, 4—*Proteacidites beddoesii* n. sp. Fig. 3a, paratype; 3b, same in phase contrast at high focus level showing apiculae. Fig. 4a, holotype; 4b, same in phase contrast.
- FIG. 5, 6—*Proteacidites angulatus* n. sp. Figs. 5a, 5b, paratype at high and intermediate focus levels. Figs. 6a-6c, holotype at high, intermediate and low focus levels.
- FIG. 7, 8—*Proteacidites adenanthoides* Cookson 1950. Figs. 7a, 7b, lectotype at high and intermediate focus levels, $\times 500$. 8a, 8b, hypotype at two focus levels, $\times 750$.
- FIG. 9—*Proteacidites crassus* Cookson 1950. Fig. 9c, lectotype, $\times 500$. 9a, detail of portion of polar surface; 9b, detail of portion of equatorial margin, $\times 500$.

PLATE 23

- FIG. 1, 2—*Proteacidites leightonii* n. sp. Figs. 1a-1c, holotype at three focus levels, $\times 750$. Fig. 2, portion of paratype showing columellae, $\times 1000$.
- FIG. 3—*Proteacidites grandis* Cookson 1950. Lectotype in interference contrast, $\times 325$.
- FIG. 4, 5—*Proteacidites reticulatus* Cookson 1950. Fig. 4, neotype, $\times 750$. Figs. 5a-5c, hypotype at three focus levels.
- FIG. 6-8—*Proteacidites rectomarginis* Cookson 1950. Figs. 6a, 6b, portion of hypotype at high and intermediate focus levels. Fig. 7a, 7b, apertural area of another hypotype, sexine lacking. Fig. 8, another hypotype, $\times 750$.

PLATE 24

- FIG. 1—*Proteacidites tuberculatus* Cookson 1950. Figs. 1b, 1c, high and low focus levels of hypotype; 1a, portion of same at intermediate focus level, $\times 750$.
- FIG. 2, 3—*Proteacidites stipplatus* n. sp. Fig. 2a, paratype; 2b, portion of same in interference contrast. Figs. 3a, 3b, holotype at high and intermediate focus levels, $\times 750$.
- FIG. 4, 5—*Proteacidites recavus* n. sp. Fig. 4, paratype, $\times 750$. Figs. 5a-5c, holotype at high, intermediate and low focus levels, $\times 750$.
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PLATE 25

- FIG. 1, 2—*Proteacidites symphyonemoides* Cookson 1950. Figs. 1a-1c, lectotype at three focus levels. Figs. 2a, 2b, hypotype at high and intermediate focus levels.
- FIG. 3—*Proteacidites pseudomoides* n. sp. Figs. 3a, 3b, holotype at two focus levels; 3c, same in phase contrast.
- FIG. 4—*Proteacidites obscurus* Cookson 1950. Figs. 4a, 4b, hypotype at two focus levels.
- FIG. 5—*Proteacidites latroensis* Harris 1966. Fig. 5b, hypotype; 5a, same in phase contrast.
- FIG. 6, 7—*Proteacidites tenuixinus* n. sp. Fig. 6, paratype in phase contrast. Figs. 7a, 7b, holotype at high and intermediate focus levels; 7c, same in phase contrast.
- FIG. 8—*Proteacidites incurvatus* Cookson 1950. Figs. 8a, 8b, lectotype at high and intermediate focus levels in interference contrast, $\times 325$.
- FIG. 9—*Triorites magnificus* Cookson 1950. Fig. 9b, hypotype at high focus; 9a, portion of same at intermediate focus level, $\times 750$.

PLATE 26

- FIG. 1—*Proteacidites pachypolus* Cookson & Pike 1954. Figs. 1a, 1b, portion of lectotype at two focus levels; 1c, same at intermediate focus level.
- FIG. 2—*Proteacidites asperopolus* Stover & Evans 1973. Topotype.
- FIG. 3-5—*Helciporites astrus* n. gen., n. sp. Figs. 3a, 3b, holotype at high and intermediate focus levels. Figs. 4a, 4b, equatorial views of paratype. Fig. 5, another paratype.
- FIG. 6—*Malvacipollis diversus* Harris 1965. Figs. 6a, 6b, hypotype at two focus levels.
- FIG. 7-9—*Malvacipollis subtilis* n. sp. Fig. 7, paratype. Figs. 8a, 8b, another paratype showing apertures. Figs. 9a-9c, holotype at three focus levels.
- FIG. 10, 11—*Periporopollenites demarcatus* n. sp. Figs. 10a-10c, paratype at three focus levels; 10d, portion of same in phase contrast. Figs. 11c, 11d, holotype at high and intermediate focus levels; 11a, 11b, portion of same in phase contrast.
- FIG. 12—*Periporopollenites vesicus* n. sp. Figs. 12a-12c, holotype at high, intermediate and low focus levels.

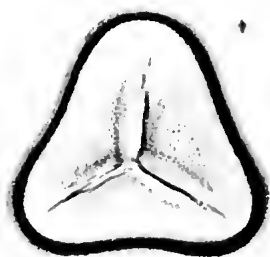
PLATE 27

- FIG. 1—*Anacolosidites acutullus* Cookson & Pike 1954. Figs. 1a-1c, lectotype at three focus levels.
- FIG. 2, 3—*Haloragacidites amolus* n. sp. Figs. 2a, 2b, holotype at two focus levels. Fig. 3, paratype.
- FIG. 4, 5—*Haloragacidites haloragoides* Cookson & Pike 1954. Fig. 4, hypotype. Figs. 5a, 5b, equatorial views of another hypotype.

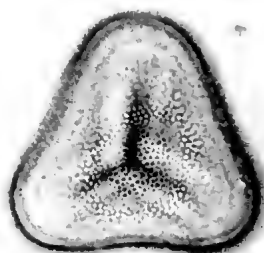
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- FIG. 7, 8—*Anacolosidites sectus* n. sp. Fig. 7, holotype. Fig. 8, paratype.
- FIG. 9, 10—*Triporopollenites bellus* n. sp. Figs. 9a-9c, holotype at three focus levels. Figs. 10a, 10b, paratype at high and intermediate focus levels.
- FIG. 11—*Polyadopollenites myriosporites* (Cookson) n. comb. Hypotype, $\times 750$.
- FIG. 12-15—*Quadruplanus brossus* n. gen., n. sp. Fig. 12, paratype. Figs. 13a, 13b, holotype at high and intermediate focus levels. Fig. 14, another paratype lacking sexine. Fig. 15, another paratype.

PLATE 28

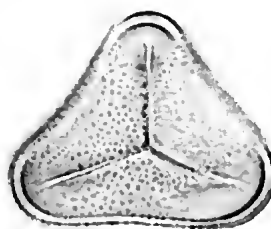
- FIG. 1—*Bysmapollis emaciatius* n. gen., n. sp. Figs. 1a-1c, holotype at three focus levels.
- FIG. 2—*Paripollis ochesis* n. gen., n. sp. Figs. 2a-2c, holotype at three focus levels.
- FIG. 3—*Gephyrapollenites calathus* n. sp. Figs. 3a-3c, holotype at three focus levels.
- FIG. 4-6—*Gephyrapollenites wahooensis* n. sp. Figs. 4a, 4b, holotype at high and intermediate focus levels. Figs. 5a, 5b, paratype as above. Figs. 6a, 6b, another paratype as above.
- FIG. 7—*Gephyrapollenites cranwellae* n. gen., n. sp. Figs. 7a-7c, holotype at high, intermediate and low focus levels; 7d, same in interference contrast.



1a



1b



2



3



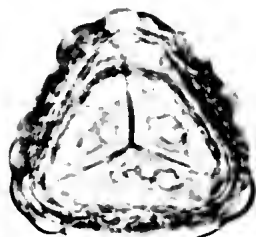
5a



7a



4a



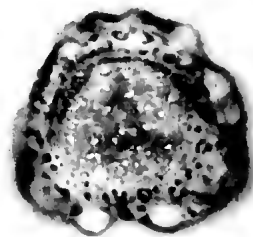
5b



7b



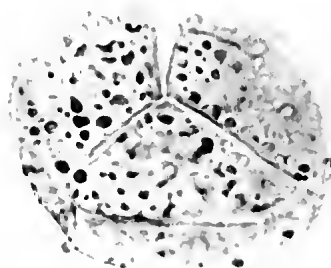
4b



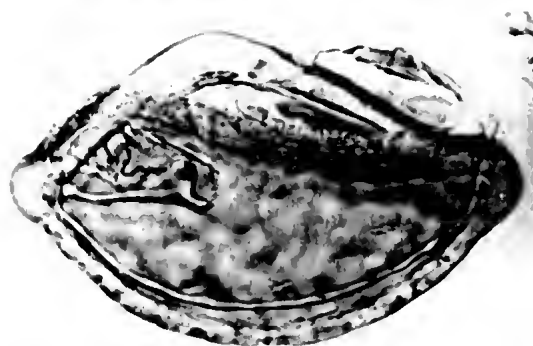
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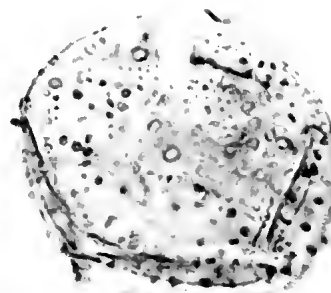
7c



8a



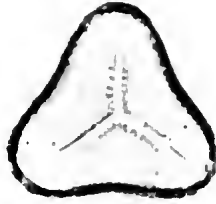
6



8b



1a



3a



4a



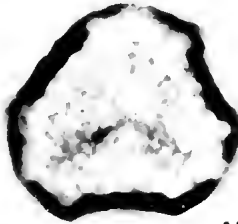
6a



1b



3b



4b



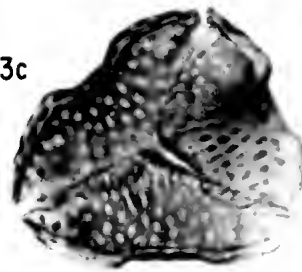
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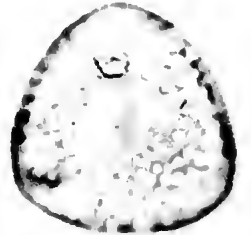
1c



3c



5



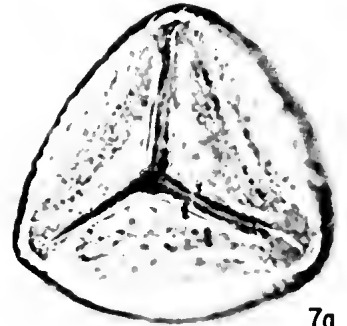
6c



2a



8a



7a



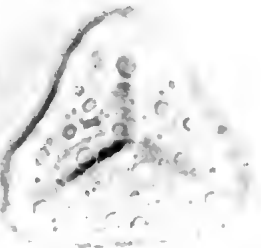
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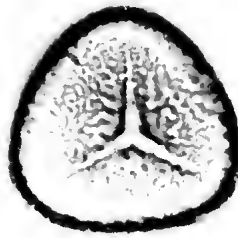
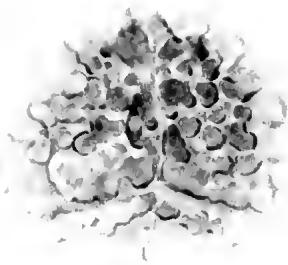
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7b



2c

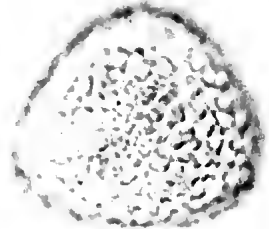
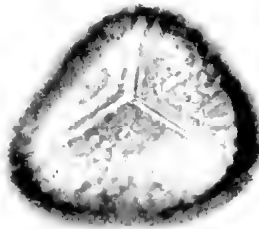


1a

1b

2a

2b

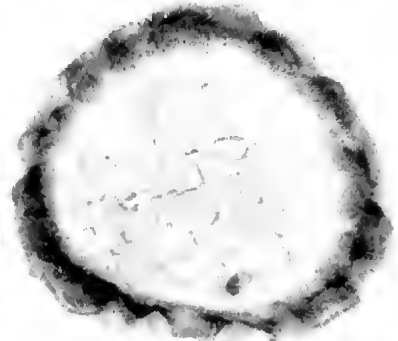
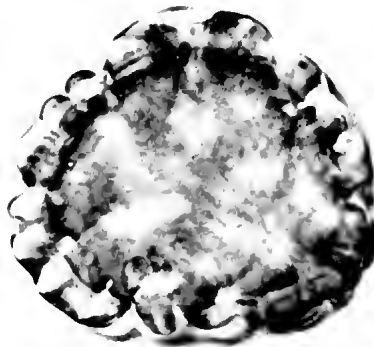


1c

3a

3b

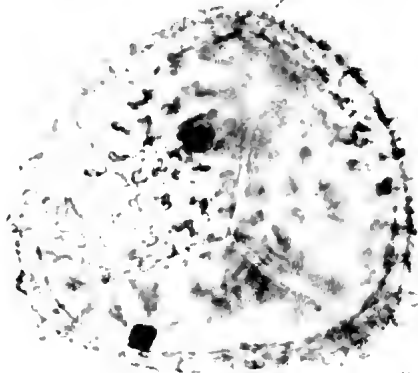
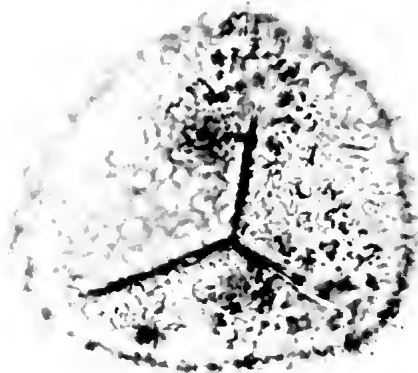
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4a

4b

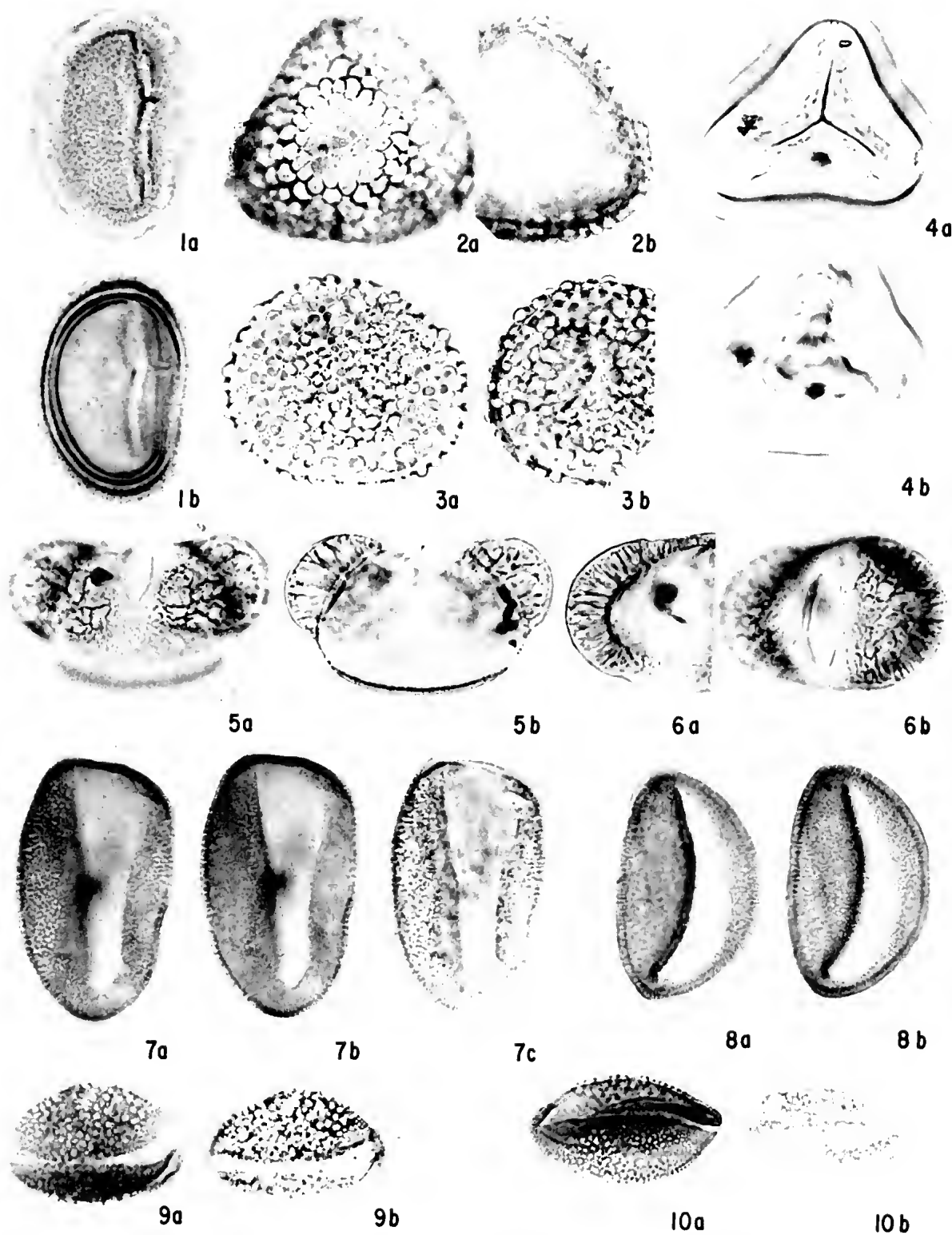
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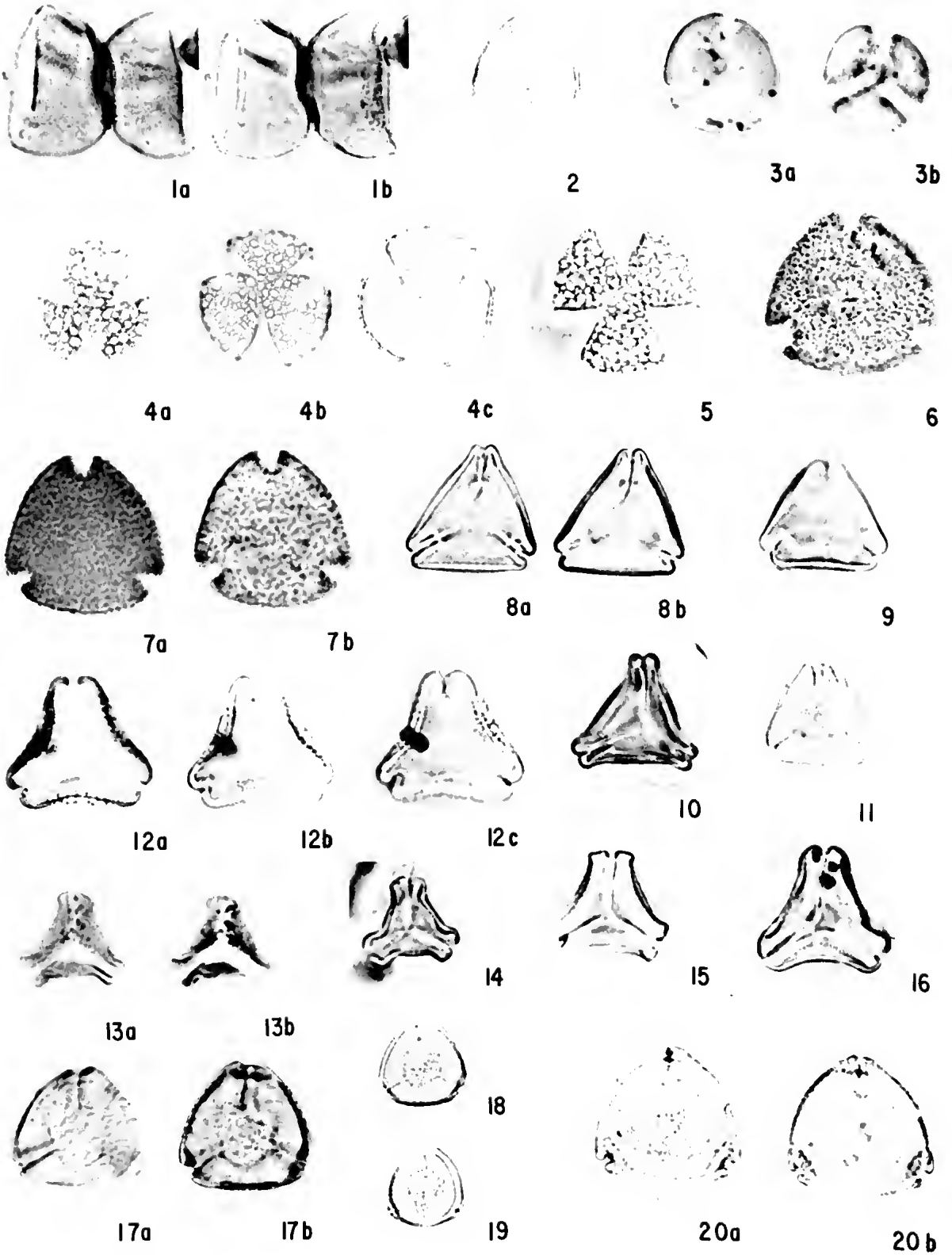


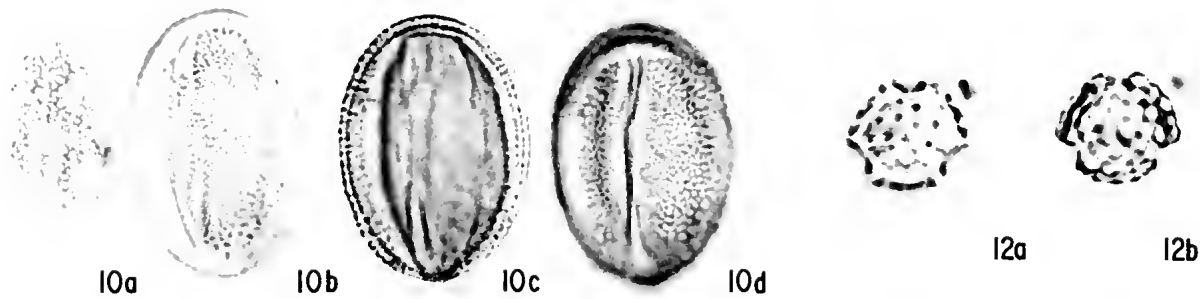
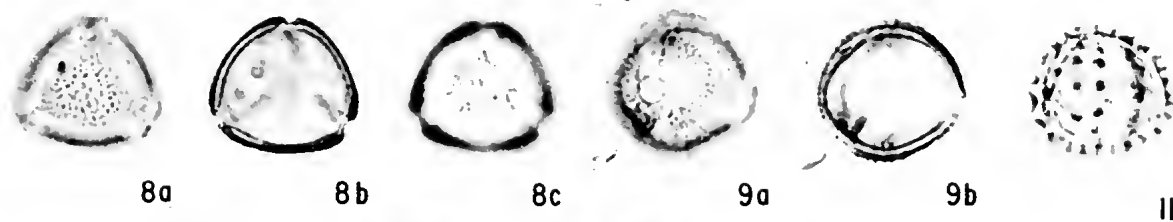
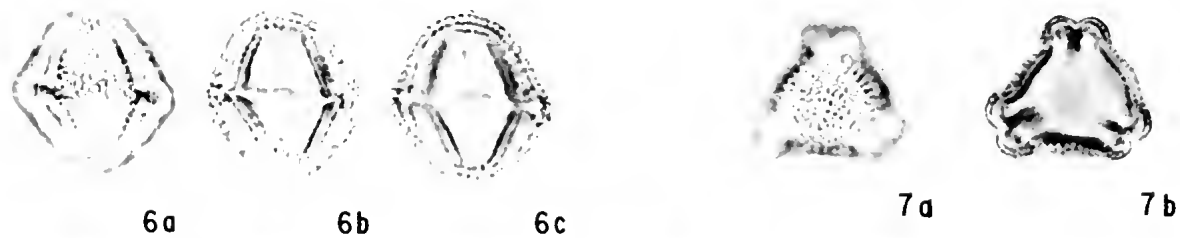
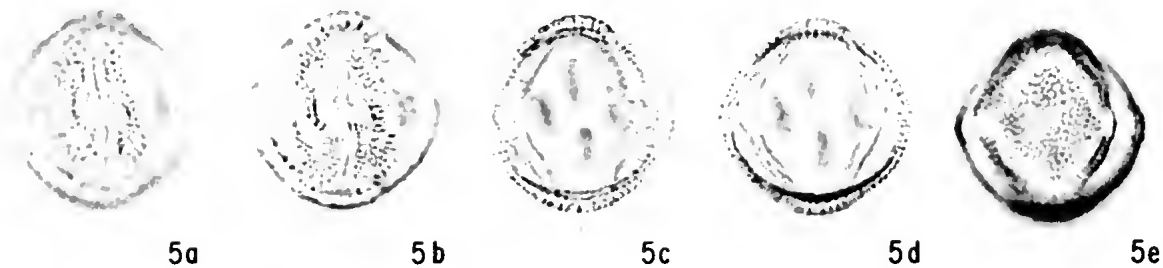
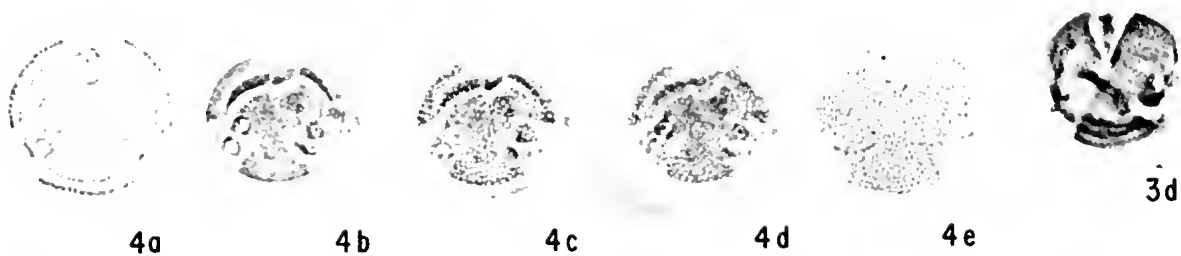
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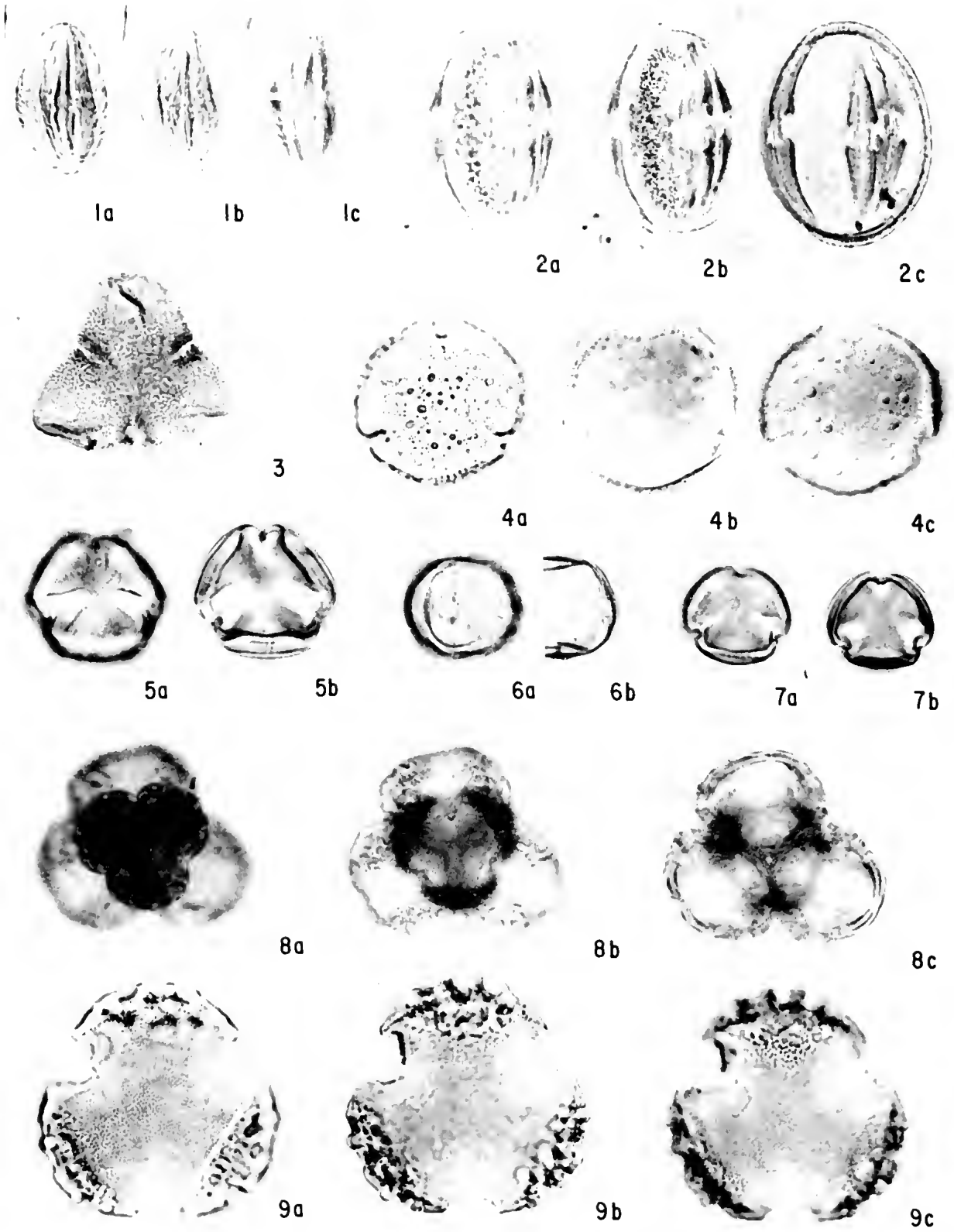
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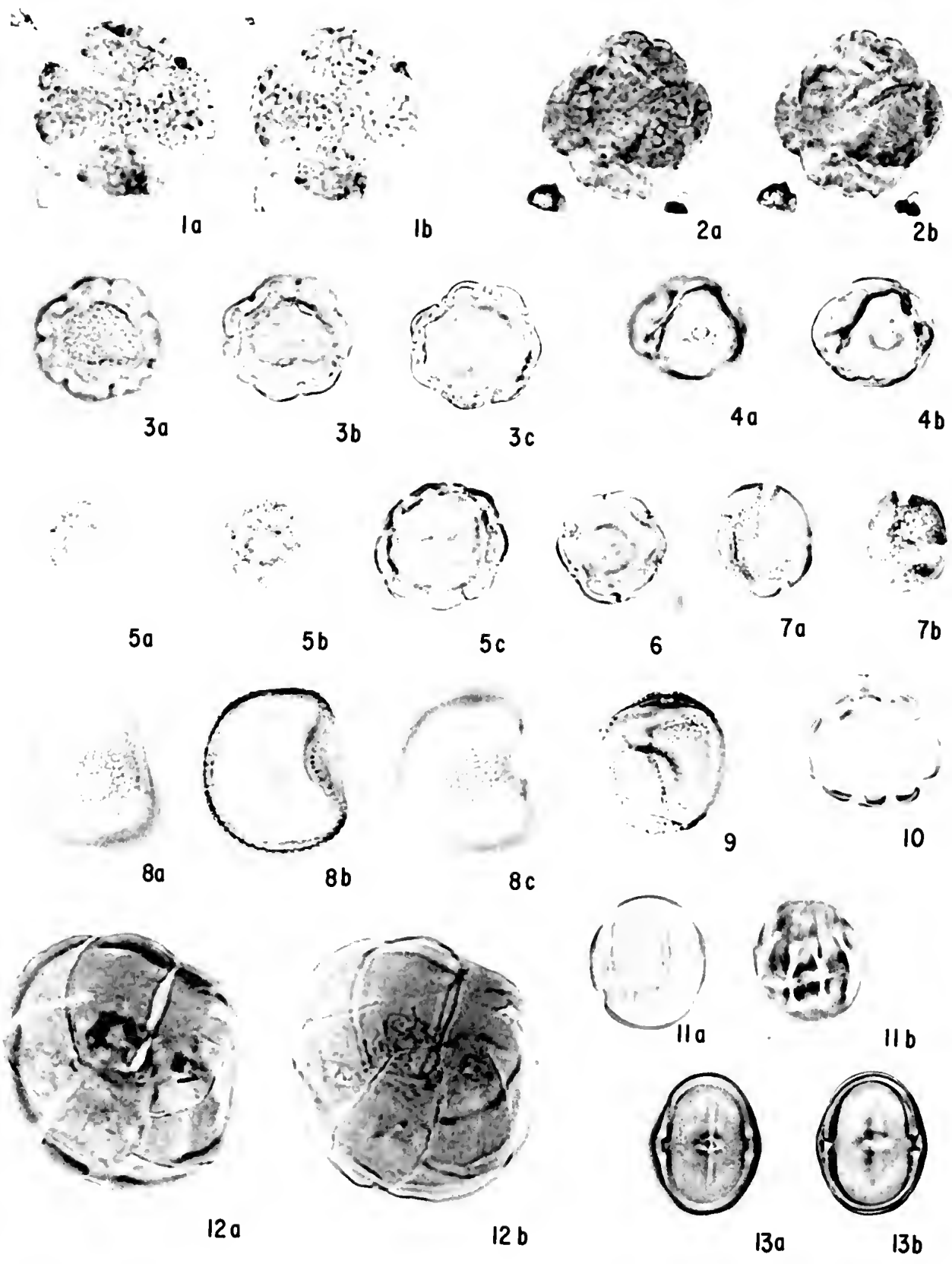
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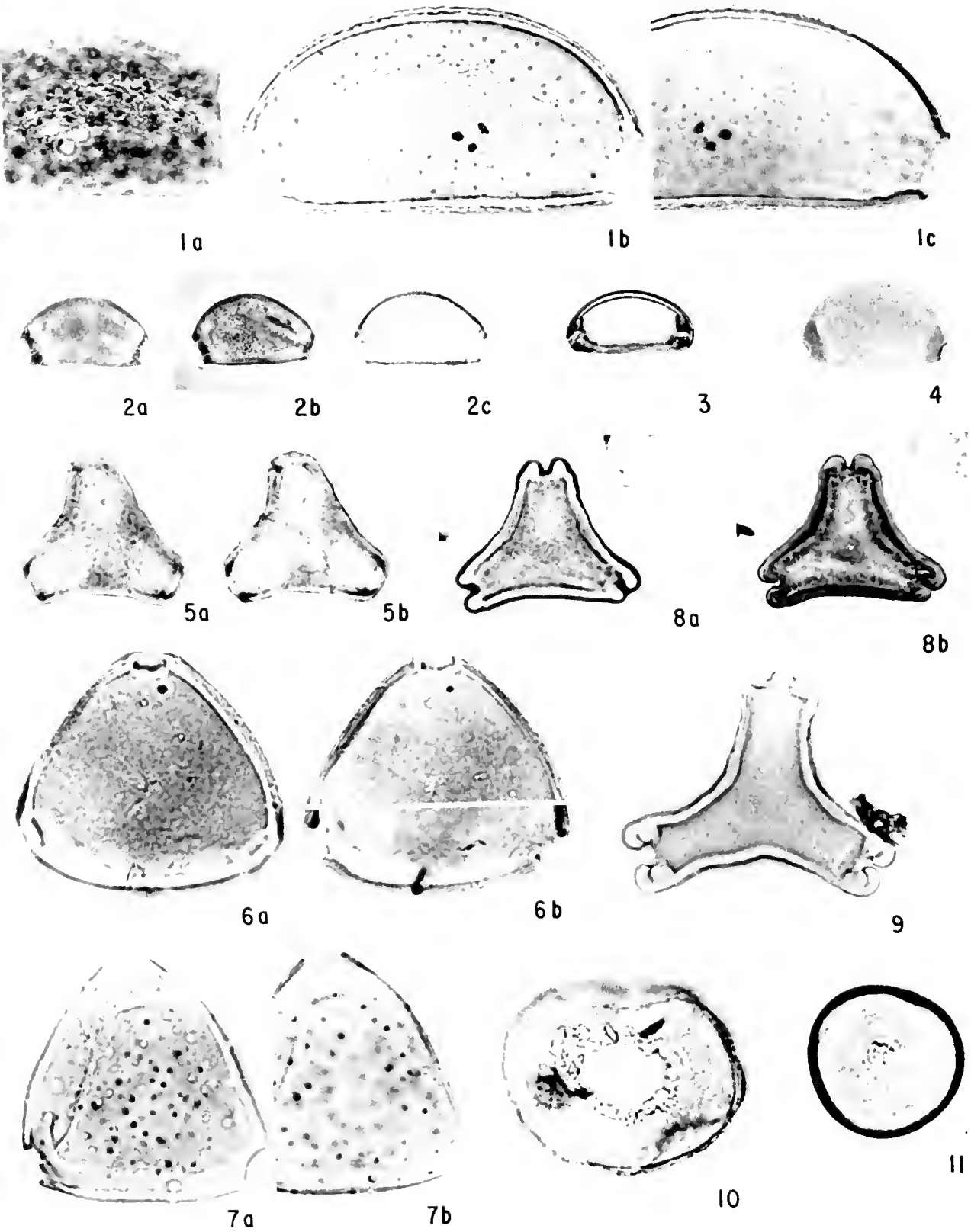


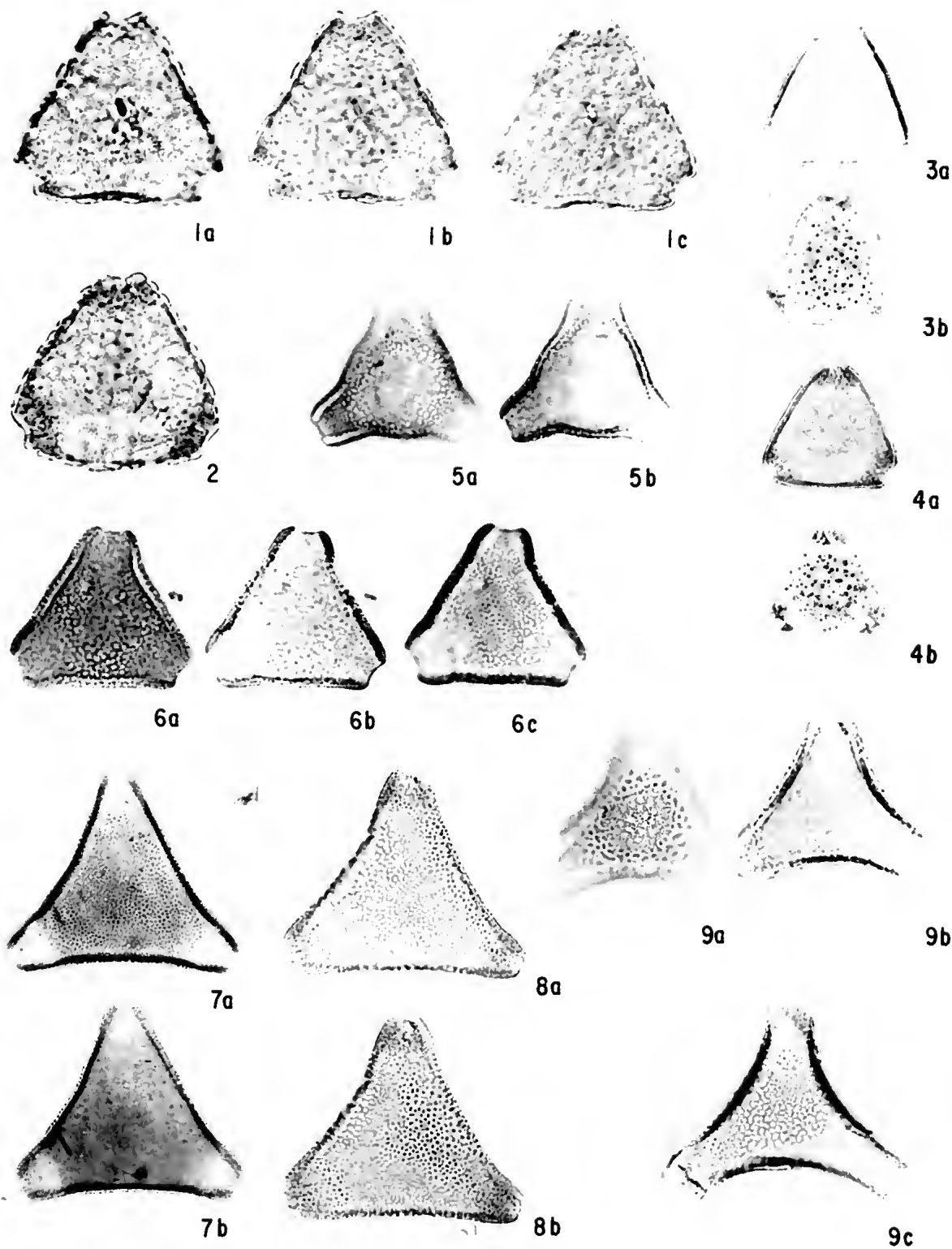










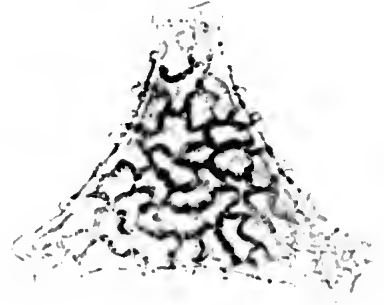




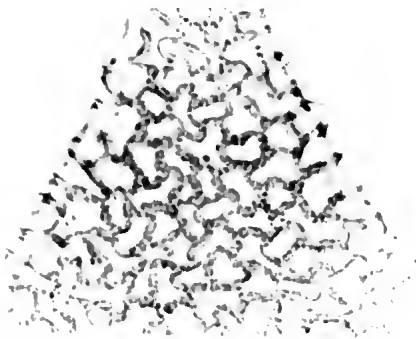
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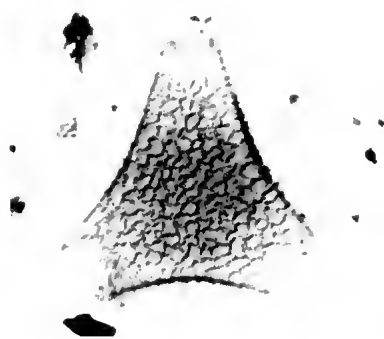
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1c



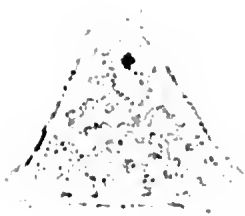
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3



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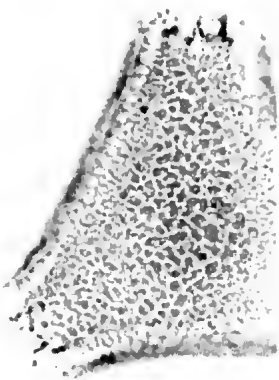
5a



5b



5c



6a



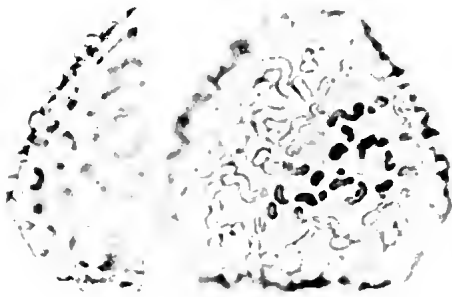
6b



7a,b



8



1a

1b



1c



3a



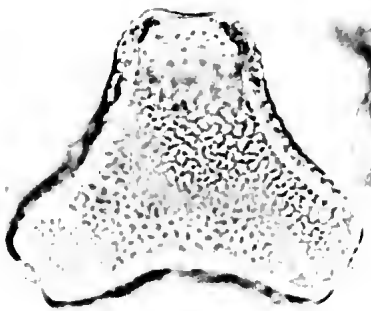
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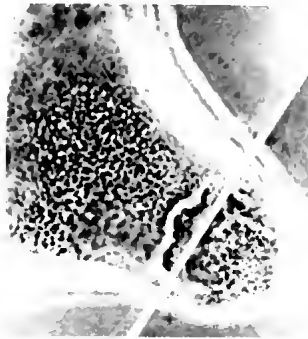
2b



3b



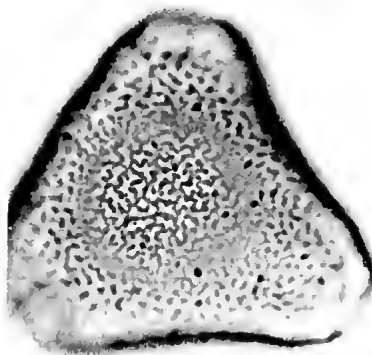
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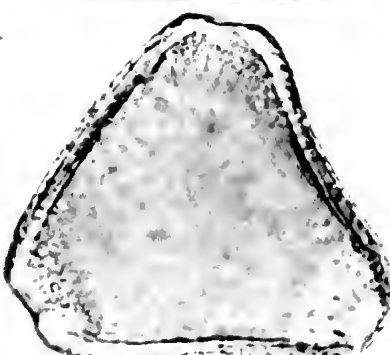
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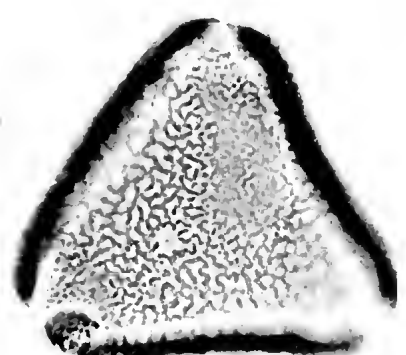
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5a



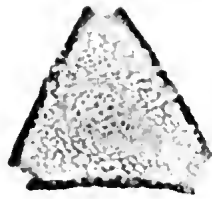
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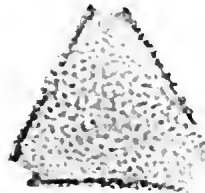
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1a



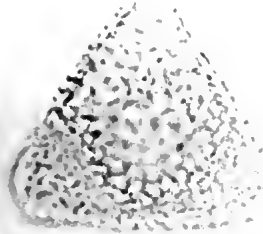
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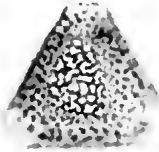
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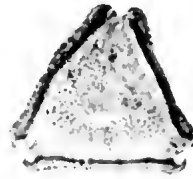
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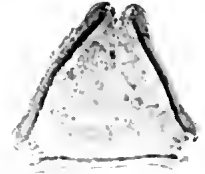
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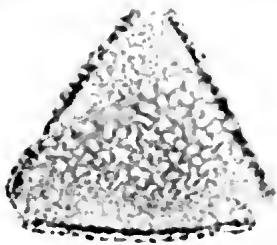
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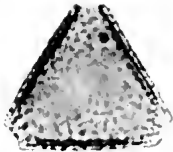
4a



4b



1c



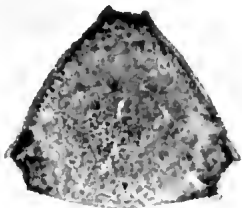
2b



5a



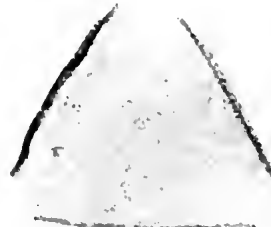
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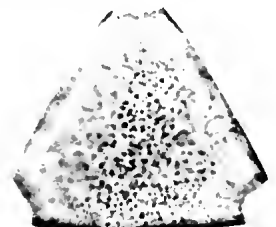
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7a



7b



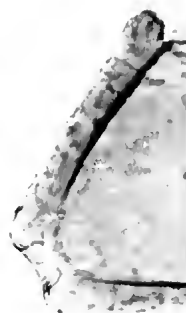
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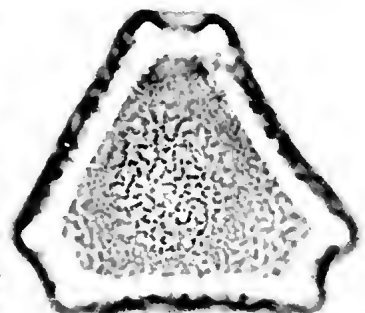
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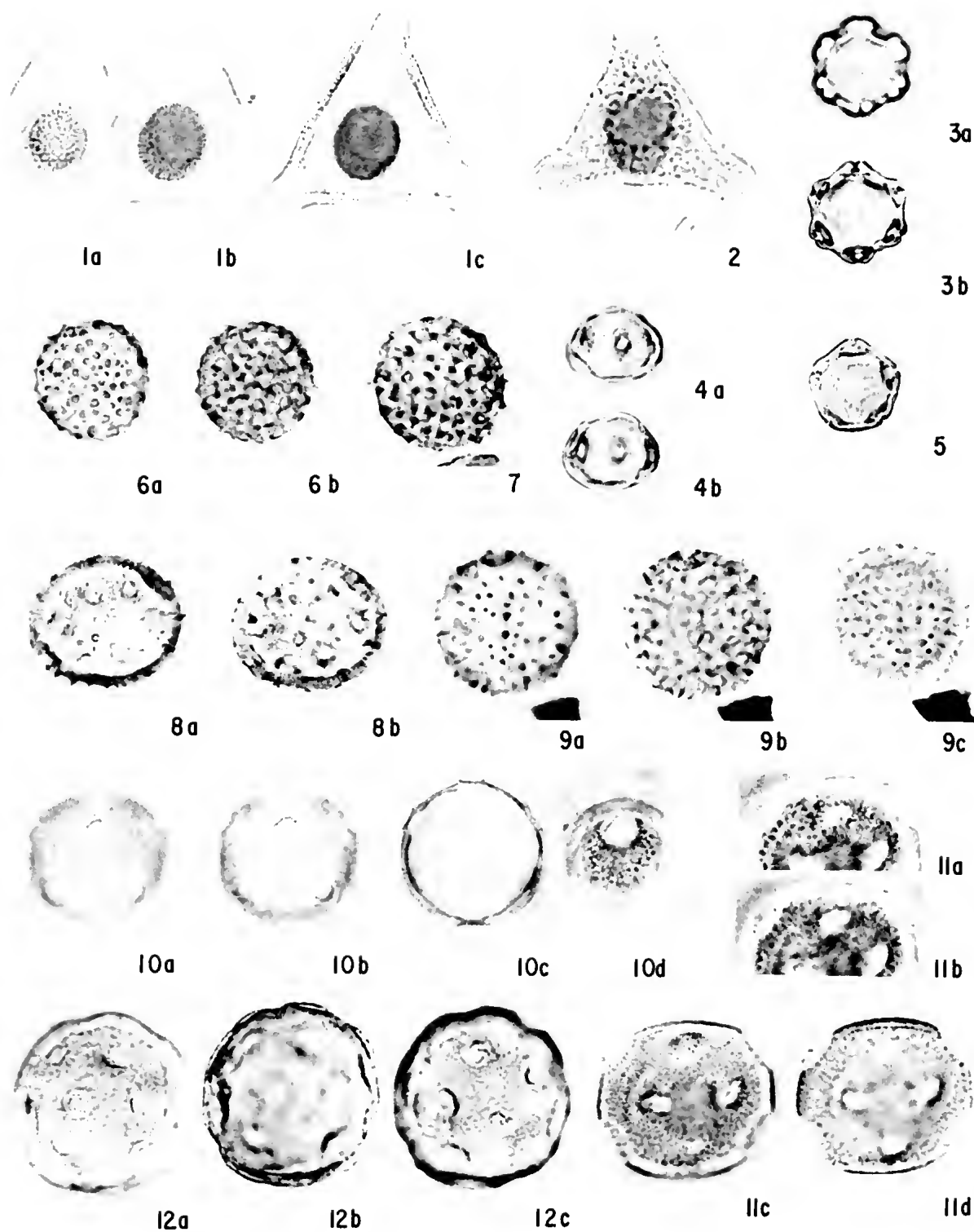
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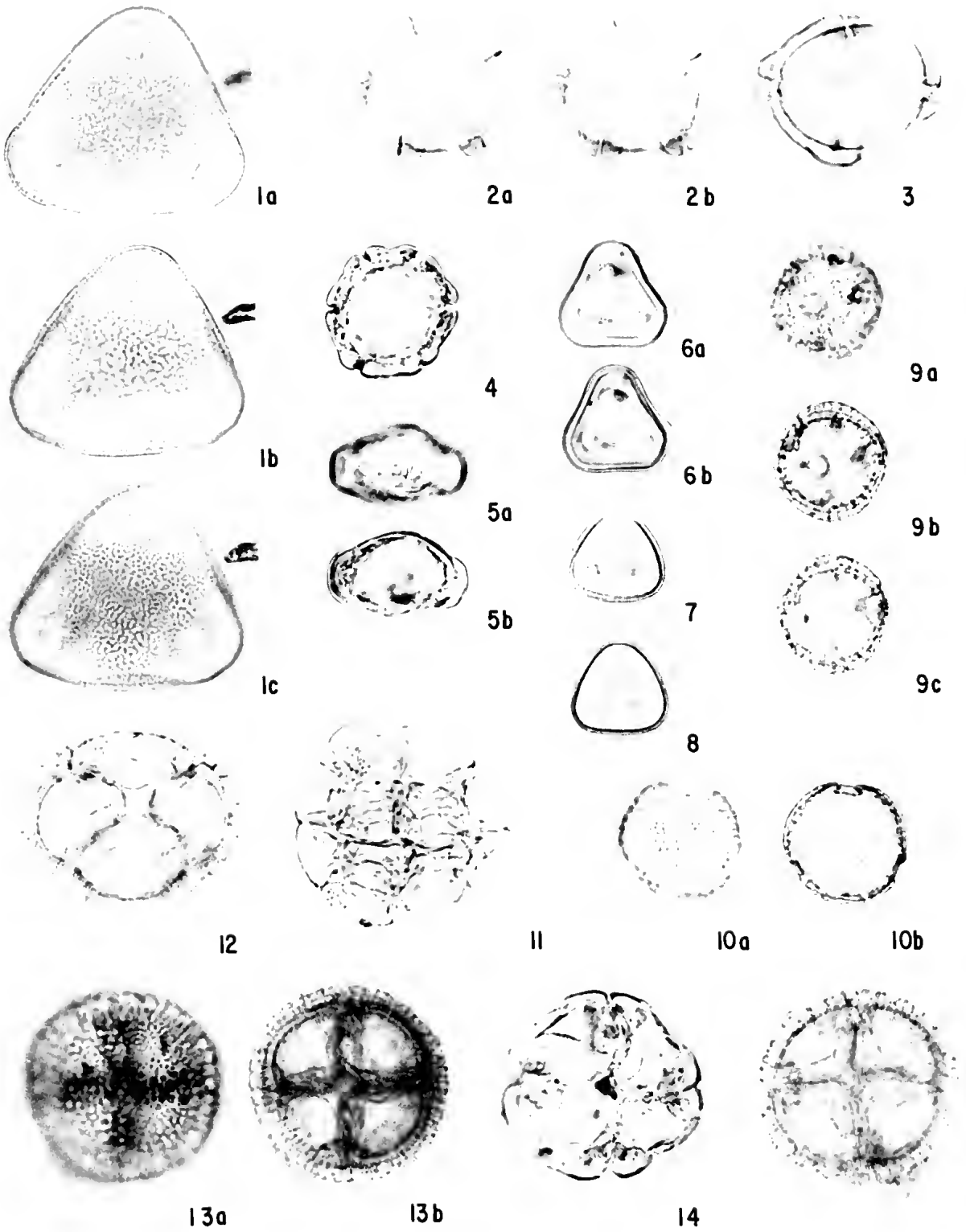


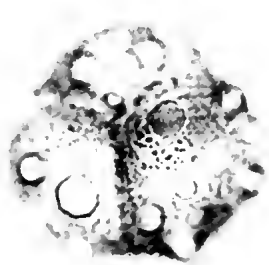
9a



9b







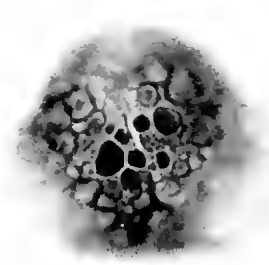
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1b



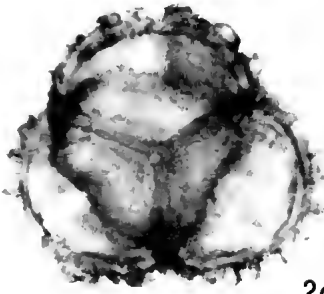
1c



2a



2b



2c



3a



3b



3c



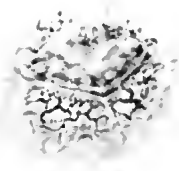
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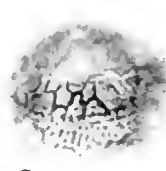
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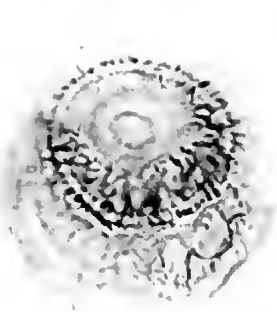
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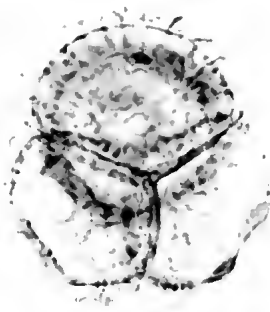
6a



6c



7a



7b



7c



7d

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| MILLIKAN DR. C.R. DSC, 29 GODDWIN ST, GLEN IRIS, VIC 3148 | 1915 |
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MEMBERS

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| AITCHISON, DR. G. D. ME PH, O, 2 'CHELMSFORD CLOSE', 27 GLENBROOK AVE., E. MALVERN, VIC 3145 | 1959 |
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| ANDREWS, PROF. J. MA PHD CANTAR, DEPT. OF GEOGRAPHY, MELB. UNIV., PARKVILLE, VIC, 3052 | 1983 |
| APLIN G.J. BA HONS, DIP, ED, MONASH TEACHERS COLLEGE, BLACKBURN RD., NORTH CLAYTON, VIC 3168 | 1967 |
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* At June 30th, 1972. Members and Associates are requested to notify the Honorary Secretary of any change of address.

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| BLACKBURN, J.A.O., 4 MCMALE COURT, ESSENDON, VIC, 3148 | 1966 |
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| BRINE F. W., TAUNTON OAKENE COURT, MOUNT WAVERLEY, VIC 3149 | 1964 |
| BRINER, DR, G.P. MSC PHD, DEPT. AGRICULTURE CHEM, LARS, 5 PARLIAMENT PLACE MELBOURNE, VIC 3002 | 1963 |
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| BRYANT R.L. PHYSICS DEPT MONASH UNI., P.D. BOX 92 CLAYTON, VIC 3166 | 1964 |
| BUCHANAN R.A. BAGRSC MS PHD LONDON, S. WAMDA ROAD, EAST BENTLEIGH, VIC 3165 | 1968 |
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| CHAMPION R. DIP, LS MIS. DIPTRP ARAIP, PO BOX 77, EAST MELBOURNE, VIC 3002 | 1972 |
| CHINNER, J.H. BSC OXON MELB DIPFOR, FORESTRY SCHOOL MELB. UNI., PARKVILLE, VIC, 3052 | 1958 |
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| CUMING V.R. BE MECH GRAO, I.E.AUST., 31891 STAFFORD DVE., BIRMINGHAM, MICH., U.S.A 48010 | 1968 |
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| CURRY J.L. B.COM, BBA FISHER ST., FULLARTON, S.A. 5063 | 1969 |
| DAPRAGH, T.A. HSC, DIP. ED, C/O NATIONAL MUSEUM OF VICTORIA, 285 RUSSELL ST., MELBOURNE, VIC, 3800 | 1963 |
| DARVALL DR, P.L.E. P. MA MS MSC PHD, 62 WILSON ST., PRINCEB HILL, VIC 3054 | 1970 |
| DAVIE R.S. BE, MECH MIE AUST MACE, 26 ELIZABETH ST., EAST BRIGHTON, VIC 3187 | 1977 |
| DAY, P.L. BSC, 1 KINGSLEY COURT, BALLARAT, VIC 3350 | 1962 |
| DEMPSTER, J.K. BSC, 76 ILLAWARRA RD., HAWTHORN, VIC, 3122 | 1967 |
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| DOUGLAS N. BEND OF ISLANDS, KANGAROO GROUNDS, VIC 3097 | 1968 |
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| DUKE, J.R. BSC, 7 ESSON ST., SHERPARTON, VIC. 3630 | 1961 |
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| HARVEY R.J.D. BA, 28 GREY ST., BALWYN, VIC 3103 | 1969 |
| HASVONG MRS HELEN M. BA, 22 KARDELLA ST., EAST MALVERN, VIC 3145 | 1971 |
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 JONES, N.L. 7 KINGSTON ST., HAMPTON, VIC. 3188 1963
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 KING G., ORYSDALE RD., WARRANDYTE, VIC 3113 1970
 KINGSLEY H.P., FLAT 3, 6 POWER STREET, TOORAK, VIC 3142 1964
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 STAFF, DR. I. A., MSC DIPED 5YD, SCHODL BIDL, SCIENCES, LA TROBE UNIV., BUNDDRA, VIC, 3083 1967
 STELLA A. R., BARCH ARIBA, 6 ARGYLE PLACE, NDRTH CARLTON, VIC 3053 1968
 STEWART, DR. A. J., MSC, PHD, BUREAU OF MINERAL RESOURCES, P.O. BOX 379, CANBERRA CITY, ACT 2601 1961
 STOVER DR. L. E., BSC, PHD, FGS AMER, ESSD STANDARD DIL AUST LTD, GPD BOX 4847 SYDNEY, NSW 2001 1970
 STRAUSS, DP. W., 9 MDDRE ST., HAWTHORN, VIC. 3122 1963
 STREET, PROF. R., MA PHD LOND, 17 HDWIE ST., GLEN IRIS, VIC. 3146 1966
 STRUSZ, DR. D. L., BSC PHD, 97 BURNIE ST., LYONS, A.C.T. 2606 1971
 STUBBS PROF. L. L., DAGRSC, SCHODL OF AGRICULTURE, MELBOURNE UNIV., PARKVILLE, VIC 3052 1958
 STYLES, D. F., MBE BSC AMIE AUST, 14 JOHN STREET, BLACKBURN, VIC. 3130 1943
 SULLIVAN, M., 37 STRATHALLAN RD., MACLEOD, VIC. 3085 1959
 SUTTON, DR. P. R. N., DDSC LDS, 24 WELLINGTON ST., BRIGHTON, VIC. 3186 1968
 SWAN PROF. J. M., PHD DSC FAA FRACI, 28 THE RIDGE, CANTERBURY, VIC 3126 1963
 TAFT DR. B. MB BS ODR MCRA, 116 RIVERSDALE ROAD, CAMBERWELL, VIC 3124 1945
 TATTAM PROF. C. M., PHD DSC, 7 ALBERT JONES COURT, EAGLEHUNT, VIC 3084 1961
 TAYLOR, D. J., MSC, GEOLOGY DEPT., SYDNEY UNIV., SYDNEY, N.S.W. 2006 1968
 TAYLOR J. I., DIP. ARCH ARIBA, 5 HIGH STREET, SEAHAM, VIC 3193 1969
 TAYLOR M. W., 44 IRELAND AVENUE, WANTIRNA SOUTH, VIC 3152 1969
 TAYLOR MISS N., FLAT 4, ERNA COURT, 181 RIVERSDALE RD., HAWTHORN, VIC 3122 1971
 TAYLOR P. J., 21 GRANGE RD., TODRACK, VIC 3142 1968
 TENNI P. B., BSC AMIE, 641 CANTERBURY ROAD, VERMONT, VIC 3133 1932
 TEX, PROF. E., DEN PHD (LEYDEN), C/O GEOL. MIN. INST. R. U. V., LEIDEN ST. U., GARENMARKT 18, LEYDEN, HOLLAND 1955
 THOMAS, F. J. D., BSC HONS ARCS, BS WARRANDYTE RD., RINGWOOD, VIC. 3134 1944
 THOMAS, DR. G. A., BSC PHD, GEOLOGY DEPT., MELB. UNIVERSITY, PARKVILLE, VIC. 3052 1963
 THOMPSON B., BSC, DEPT. OF MINES, 187 RUSSELL ST MELBOURNE, VIC 3000 1939
 THOMPSON, G. D., AMIE AUST MDN, MIBF, 4 BRDOKS PLACE, YARRAVILLE, VIC 3013 1933
 THOMPSON, D. T., UNIT 8, MARANO COURT, 8 PARRING RD., BALWYN, VIC 3103 1958
 THOMPSON DR. J. A., MSC PHD, GENETICS DEPT., UNIV. OF MELBOURNE, PARKVILLE, VIC 3052 1958
 THORN, W., MEE MIE AUST, 9 FLORENCE AVE., KEW, VIC. 3101 1978
 THORPE F. J., 10 LOVELL STREET, HAWTHORN, VIC 3123 1958
 TIMCKE, E. M., 15 FAIRCROFT AVE., GLEN IRIS, VIC. 3146 1937
 TOWNSEND, PROF. SIR LANCE, MD HS FRCS (EDIN), UNIVERSITY OF MELBOURNE, PARKVILLE, VIC. 3052 1971
 TURLEY F. Y., 3 ARDNICK ST., MDOORABBIN, VIC 3189 1971
 TURNBULL A. R., DIP. FOR, FOREST OFFICE, BENDOC, VIC 3088 1938
 TURNER, PROF. J. S., MA PHD MSC FAA, BOTANY DEPT., UNIV. OF MELBOURNE, PARKVILLE, VIC 3052 1931
 TYLER, A. N., SIMSONS RD., LARONER, VIA WARRAGUL, VIC. 3821 1964
 UHL, A. M., MIE AUST MIE LOND MAIE NY, 1 GWENDA AVE., BLACKBURN, VIC. 3130 1961
 VALE, W. H., 17 WALSTAB ST., EAST BRIGHTON, VIC. 3107 1968
 VASEY MRS. F. R. BSC (MELB), 6 CITRUS CRT., DONCASTER, VIC 3108 1969
 VAUGHAN DR. G. N., PHD MSC, INGLEBY, UPPER BEACONSFIELD, VIC 3008 1962
 VERSO, DR. M. L., MB BS UTM MCPA, BLOOD BANK, 114 FLINDER ST., MELBOURNE, VIC. 3000 1970
 WADE DR. MARY BSC PHD, QLD MUSEUM, GREGORY TERRACE, FORTITUDE VALLEY, QLD 4006 1971
 WAITE D. R., LDSC LDSE FRSH, 190 MAIN ST., CROYDON, VIC 3136 1961
 WAKEFIELD, N. A., MSC, MONASH TEACHERS COLLEGE, CLAYTON, VIC 3168 1972
 WALLIS G. L., ARMIT, 313 ELGAR RD., BOX HILL, VIC 3129 1968
 WALLDROP, PROF. A. B., MSC (TAS) PHD (LEEDS) DSC (MELB), 3 GWENDA AVE., BLACKBURN, VIC. 3130 1966
 WARK, DR. J. MCF. CBE DSC, 117 VARRANBAT AVENUE, BALWYN, VIC. 3103 1967
 WARNEKE R. M., BAGHSC MSC, FISHERIES & WILDLIFE DEPT., 632 BURKE ST., MELBOURNE, VIC 3000 1968
 WARREN G. T., 48 JONES COURT, ROSANNA, VIC 3084 1963
 WARREN, PROF. J. W., MA PHD, ZOOLOGY DEPARTMENT, MONASH UNIVERSITY, CLAYTON, VIC. 3168 1969
 WASS J. M., 113 NICHOLSON STREET, EAST CDBURG, VIC 3038 1968
 WATSON, G. F., ZOOLOGY DEPARTMENT, MELB. UNIVERSITY, PARKVILLE, VIC. 3052 1961
 WATSON, MRS. J., ASMB AMTC, 74 NIMMO ST., ESSENDON, VIC. 3040 1969
 WEBB A. W. F., M. SC FDR, DIP FOR DODN, 5 GRENVILLE ST., BOX HILL, VIC 3128 1968
 WEBB G. C., BSC DIPED MELBOURNE, 47 FORTUNA AVE., NORTH BALWYN, VIC 3104 1959
 WEICKHARDT, L. W., MSC FRACI, 123 CANTENBURY RD., CANTERBURY, VIC. 3126 1967
 WEST, A. L., BA DIPSDCSTUD, 17 THE RIDGE, KNOXFIELD, VIC. 3180 1968
 WESTE MRS. G., MSC, 29 GILBERT GROVE, BENTLEIGH, VIC 3204 1939
 WHITTENHALL, DR. M. N. B., MD BS MRCP FRACP, 14 PARLIAMENT PLACE, EAST MELBOURNE, VIC. 3002 1967
 WHARTON, J. C. F., BSC, 10 RAYMOND ST., ASHWOOD, VIC. 3147 1938
 WHITE, PROF. M. J. D., DSC LOND FRG FAA, GENETICS DEPARTMENT, MELB. UNIVERSITY, PARKVILLE, VIC. 3052 1938
 WHITE, R. K., FIPAA, 414 COLLINS ST., MELBOURNE, VIC. 3000 1963
 WHITELAW, J. J., BME, 76 TODRACK RD., CAMBERWELL, VIC. 3124 1967
 WHITER, M. R., 13 ANDERSONS RD., EAST HAWTHORN, VIC. 3123 1959
 WHITING, R. G., BME, 3 PARKSIDE AVE., BALWYN, VIC. 3103 1934
 WILCOCK, A. A., BSC BED, GEOGRAPHY DEPARTMENT, MELB. UNIVERSITY, PARKVILLE, VIC. 3052 1963
 WILKINSON M. E., DSC, MILL VIEW, WIRTH STREET, BENDIGO, VIC 3550 1968
 WILLIAMS C. M., AASA, 17 SEYMOUR GROVE, BRIGHTON BEACH, VIC 3186 1972
 WILLIAMS D. A., DIP. APP. PHYS. ARMIT, 35 HAMPTON ST., WEST ESSENDON, VIC 3040 1969
 WILLIAMS T. W., 90 STUDLEY RD., IVANHOE, VIC 3079 1969
 WILLIAMS DR. W. D., PH.D, ZOOLOGY DEPT. MONASH UNIV., CLAYTON, VIC 3168 1949
 WILLIS, A. G., MGC, ZOOLOGY DEPARTMENT, MELB. UNIVERSITY, PARKVILLE, VIC. 3052 1964
 WILLIS J. H., BSC, 102 HALE ST., BRIGHTON, VIC 3186 1961
 WILSON, D., BSC, 46 HODDLE ST., ESSENDON, VIC. 3040 1969
 WINSTON R. F., INST D M. INST M. 91 GRANGE ROAD, TODRACK, VIC 3142 1969
 WISE J. M., BA, DIP. ED, BURWOOD TEACHERS COLLEGE, 221 BURWOOD RD., BURWOOD, VIC 3125 1970
 WOOD MISS C. M., RA. MACE., 4A GLENROY ROAD, HAWTHORN, VIC 3122 1963
 WOODFORD, E. R., 40 ROSE ST., MCKINNON, VIC. 3204 1965
 WOODRUFF, D. S., BSC, BIOLOGICAL LABS., HARVARD UNIV., 16 DIVINITY AVE., CAMBRIDGE, MASS, USA 02138 1970
 ZEIDLER D. R., B. SC., 2A GRANGE AVENUE, CANTERBURY, VIC 3126

ASSOCIATES

| | |
|---|------|
| BAKER A.A., P.O. BOX 164, MORNINGTON, VIC. 3931 | 1946 |
| BALOHIN J.C., BSC BAGRSC, 33 WALNUT AVE., MILDURA, VIC. 3580 | 1949 |
| BAHFORO, W.E., BE(MONS), 352 OAKS STREET, MIOOLE PARK, VIC. 3206 | 1963 |
| BAUM F.T., 1 BERYL ST., NUNAWADING, VIC. 3131 | 1967 |
| BEAVIS MRS. J.M., P.O. BOX 67, CLAYTON, VIC 3168 | 1965 |
| BISHOP J.J., BA, HIGH SCHOOL, HOE, VIC 3825 | 1950 |
| BOCM P.E., BSC, 32 SWAY FIELD RD., MT. WAVERLEY, VIC 3149 | 1957 |
| BOLLEN P.W., 5 MERCER RD., ARMAOALE, VIC 3143 | 1957 |
| BOWEN K.G., BSC, 2 BURKE ST., MONTMORENCY, VIC. 3894 | 1964 |
| BOWLER J.M., MSC, DEPT. OF GEOGRAPHY, INST. OF ADV. STUD., A.N.U., CANBERRA, ACT 2688 | 1960 |
| BURN R., 3 NANTES ST., NEWTOWN, GEELONG, 3228 | 1956 |
| BLTTERY S. H., 15 JUOITH COURT, MT. WAVERLEY, VIC 3149 | 1952 |
| CARR MRS. STELLA G. M., MSC, RES. SCHL. BIDL. SCIENCES, A.N.U., P.O. BOX 475, CANBERRA, ACT, 2601 | 1937 |
| CARTER OR. A. N MSC PMO, B SCOTT ST., MAROUBRA, NSW 2835 | 1947 |
| CLARKE W. C., 8E BSC OIPEO, 2 MEES CRESCENT, FAULCONBRIDGE, NSW 2776 | 1957 |
| CLIFFORD OR. M. T. MSC PHO, BOTANY DEPT, QUEENSLAND UNIV., ST. LUCIA, QLD, 4067 | 1949 |
| COBBETT A. M., 4 OXFORD CLDSE, MODRABBIN, VIC. 3139 | 1951 |
| COCHRANE G.W., MSC, 254 NORTH RD., EAST BRIGHTON, VIC 3187 | 1945 |
| COLLEDGE MISS JEAN, S., 13/85 PLEASANT RD., MANTHORN EAST, VIC. 3123 | 1964 |
| CORMACK, M.G., LWR. CRAWFORD PTE. BAG 39, MEYWOOD, VIC. 3304 | 1961 |
| COOPER, JAMES K. PRMIT, C/O R.HARE & ASSOCIATES, 18 LITTLE COLLINS ST., VIC. 3000 | 1965 |
| COVENTRY, A.J., NATIONAL MUSEUM OF VICTORIA, RUSSELL ST. MELBOURNE, VIC 3000 | 1966 |
| OAVIES, A.F., WAYSIOE OEL BRIDGEWATER RD., PORTLAND, VIC. 3305 | 1965 |
| DE JONK, B.T.R., 13 ANOLANA AVE., MULGRAVE, VIC. 3170 | 1964 |
| DICKINS OR. J. MCG. MSC, PMO, BUREAU OF MINERAL RESOURCES, CANBERRA, A.C.T. 2600 | 1952 |
| ELMORE, L.K.W., P.O. BOX 317, HAMILTON, VIC. 3380 | 1964 |
| ENGLISH, J.R., 382 LOWER HEIOELBERG RD., EAST IVANHOE, VIC. 3879 | 1966 |
| FINLAY MISS C.J. BSC, GEOLOGY DEPT, UNIV. OF MELBOURNE, PARKVILLE, VIC 3082 | 1958 |
| FISHER, OR. EILEEN E. PHD, 1 BALWYN RD., CANTERBURY, VIC. 3126 | 1949 |
| FORREST, J.M., METROPOLITAN FARM, WERRIBEE, VIC 3038 | 1954 |
| FROSTICK, A.C., 12 POWER ST., NORTH WILLIAMSTOWN, VIC. 3816 | 1933 |
| GAMBLE O.S., 51 GROVE RD., MANTHORN, VIC 3122 | 1964 |
| GOSTIN OR. V.A. MSC, PMO, DEPT. OF GEOLOGY, ADELAIDE UNIV., ADELAIDE, SA 5001 | 1963 |
| HAYTON, H., 55 MUNT CRESCENT, ASCOT VALE, VIC. 3032 | 1965 |
| HOPE MRS. J. BSC, C/O DEPT. BIOGEOG. SCH. PACIFIC STUDIES, ANU BOX 4 CANBERRA, ACT 2600 | 1967 |
| JOHNS OR. M.W. BSC MB BS, 187 RATHMINES RD., MANTHORN EAST, VIC 3123 | 1958 |
| JONES B.C. MA, LLB, ACTT, 24 PUROY AVENUE, DANDENONG, VIC 3175 | 1965 |
| KENLEY, P.R. BSC, 14 YARRABEE COURT, MT. WAVERLEY, VIC. 3149 | 1943 |
| KERSHAW R.C., 43 WEST TAHAR RD., LAUNCESTON, TAS. 7268 | 1936 |
| LAWRENCE, C.R. BSC, 4 UNA ST., MT. WAVERLEY, VIC. 3149 | 1958 |
| LEARNHONTH, A.P., C/O 17 LEONARD ST., SUNSHINE, VIC. 3820 | 1955 |
| LIM MRS. ELAINE M. BSC, PRIVATE BOX 5406CC, GPO MELBOURNE, VIC 3801 | 1967 |
| MARSDEN, M.A.H. BSC, GEOLOGY DEPT., UNIV. OF MELBOURNE, PARKVILLE, VIC 3052 | 1952 |
| MATTHEAI MRS. G BA DIPED, 146 GATEHOUSE ST., PARKVILLE, VIC 3852 | 1959 |
| MCLAURIN, A.N., COUANGALT, VIA GISBORNE, VIC. 3437 | 1963 |
| MOONEY, M.J., DOUTHIE ROAD, SEVILLE, VIC 3139 | 1963 |
| HOORS, OR. M.T. PHD, BSC, 27 ROSEDALE RD., GLEN IRIS, VIC 3146 | 1965 |
| NEILSON, J.L. BSC, 55 GLYNOD RD., CAMBERWELL, VIC. 3124 | 1952 |
| NETHERWAY G.C., 686 DANA ST., BALLARAT, VIC. 3358 | 1958 |
| NICHOLSON B.M. BAGRSC, SOIL CONSERVATION AUTHORITY, 32 PYKE ST., BAIRNSDALE, VIC 3875 | 1963 |
| PASSIOURA, OR. J.B., CSIRO. DIV. OF LAND RESEARCH, P.O. BOX 109 CANBERRA, A.C.T. 2601 | 1961 |
| PATON R.J., 295 OORSET RD., BORDNIA, VIC 3155 | 1968 |
| PICKEN I.O., B BAHODN RD., ELTHAM, VIC. 3895 | 1967 |
| PINCHES MRS. M., 25 GREENHILLS AVE., MONTROSE, VIC. 3765 | 1943 |
| PRETTY R.B., BSC, PRIVATE MAIL BAG 7C, COBARGO, N.S.W. 2547 | 1922 |
| RASH, K.E., 319 HUFFFRAY STREET, BALLARAT, VIC. 3350 | 1960 |
| RAWLINS R.J. BSC, PO BOX 3644, OARWIN, N.T. 5794 | 1957 |
| REED OR. K.J. BSC, MS, PHD, GULF RES. & DEV. CO., PO OPAHER 2038, PITTSBURGH, PENNSYLVANIA, USA 15230 | 1958 |
| RIMINGTON K.N. BSC, 27A GORDON STREET, HAMPTON, VIC 3188 | 1948 |
| ROME R.K. BSC. FOR, 27 BRODY ST., WANGARATTA, VIC. 3677 | 1965 |
| SEARLE S.S., METROPOLITAN FARM, WERRIBEE, VIC. 3830 | 1954 |
| SEEBECK J.M. BSC, HARRAWONG, ERITH LANE, KALDRAMA, VIC 3765 | 1967 |
| SHAW M., 16 DOUGLAS AVE., BOX HILL SOUTH, VIC. 3128 | 1956 |
| SIMPSON B. M., 13 MILLSIDE CRT., LABURNUM, VIC. 3138 | 1959 |
| SIMPSON K.G., 27 KINGSWOOD DRIVE, OINGLEY, VIC 3172 | 1967 |
| SINNOTT P.J., 17 NORHOALE RD., EAST BENTLEIGH, VIC. 3165 | 1959 |
| STONE OR. I.G. HSC. PHD., 24 ALANOALE RD., EAGLEHONT, VIC 3864 | 1965 |
| STONE, A.G., 24 ALANOALE RD., EAGLEHONT, VIC. 3884 | 1966 |
| STUBBS O., 2 COLERTIOGE ST., ELWOOD, VIC. 3134 | 1960 |
| TAYLOR T.W. HSC, BOX 7, CLONCURRY, QLD 4824 | 1961 |
| TUODENHAM W.G. BSC DIP. ED, SCHOOL OF FORESTRY, UNIV. OF MELBOURNE, PARKVILLE, VIC 3052 | 1963 |
| VANDENBERG A.H.M., 6 FREW AVE., FRANKSTON, VIC. 3199 | 1965 |
| VAN HEURS W., 18 WATTS ST., BOX HILL, VIC 3128 | 1969 |
| VASEY G.H. BCE, 6 CITRUS CRT., DONCASTER, VIC 3103 | 1936 |
| WALKER OR. A.L. C/O RESEARCH EXP. MGT. PTY. LTD., 470 COLLINS ST., MELBOURNE, VIC 3000 | 1961 |
| WHITE O.L. BSC MASC, CIVIL ENG DEPT WATERLOO UNIV., WATERLOO, ONTARIO, CANADA. | 1955 |
| WILLIAMS MRS. V.M., OPENQUI, 186 GREGORY ST., BALLARAT, VIC 3358 | 1962 |
| WYHONO A.P. MSC, C/O CSIRO, P.O. BOX 318, SOUTH MELBOURNE, VIC. 3285 | 1951 |

Royal Society of Victoria

REPORT OF THE COUNCIL FOR THE YEAR ENDING 9 MARCH 1972

The Council presents to Members of the Royal Society of Victoria its report on the activities of the Society during its 117th year.

COUNCIL—The following Office-bearers and Councillors were elected at the Annual General Meeting on 11th March, 1971.

President: Mr A. Dunbavin Butcher

Vice-Presidents: Mr L. Adams, Sir Robert Blackwood

Immediate Past President: Mr E. D. Gill

Honorary Treasurer: Professor J. D. Morrison

Honorary Librarian: Dr J. G. Douglas

Honorary Secretary: Professor A. B. Wardrop

Honorary Editor: Professor J. W. Warren

Honorary Research Secretary: Professor M. J. Canny

Honorary Development Manager: Dr G. A. Sklovsky

Honorary Assistant Secretary: Mr N. W. Morley

Council—

Dr G. D. Aitchison

Dr A. G. Brown

Mr J. H. Chinner

Mr H. C. Chipman

Mr G. A. Kaufmann

Dr P. G. Law

Professor J. F. Lovering

Mr A. E. Perriman

Professor J. M. Swan

Professor B. S. Hetzel and Professor L. L. Stubbs were elected on 10th June, 1971.

The resignations from Council of Dr D. Spencer-Jones and (in October, 1971) of Mr H. C. Chipman were accepted with regret.

At a Special General Meeting of the Society on 13th May, 1971, Laws relating to the election of Office-bearers and Councillors were amended.

Pursuant to these amendments, the Office-bearers and Councillors above-mentioned were re-elected for the year 1972 and the two vacancies on Council were filled by the election of Professor G. Burnstock and Dr D. M. Churchill.

COMMITTEES OF COUNCIL. The following Committees met during the year: Development, Publications, Library.

MEETINGS AND LECTURES. During the year, ten Ordinary and one Special meeting were held.

MARCH 11—‘Education for the Seventies’, by Dr P. G. Law.

APRIL 15—‘CSIRO in the Seventies’, by Dr J. R. Price.

MAY 13—Medal Lecture, ‘Interaction of Autonomic Nerves and Smooth Muscle Cells on Tissue Cultures and Transplants’, by Professor G. Burnstock.

MAY 21—Special Joint Meeting with the Victorian Division of ANZAAS. ‘Solvents, Solutions and Drugs—a Physical-Chemical Approach’, by Professor T. Higuchi.

JUNE 10—‘Health and Illness in the Urban Revolution’, by Professor B. S. Hetzel.

JULY 8—'Plant Diseases and the History of Man', by Professor L. L. Stubbs.

AUGUST 12—'Interactions of Science and Industry', by Professor B. O. West and Mr. J. Kolm.

SEPTEMBER 9—'Nutritional Basis of Stream Life', by Professor N. Hynes.

OCTOBER 14—Research Papers: 'Practical Application of the Zurich-Montpellier System of Phytosociology', by Dr P. Bridgewater. 'What happens when the Great Ice Ages descend on the Australian Alps', by Dr J. A. Peterson. 'A Study of the Peramelid Tarsus', by L. G. Marshall.

NOVEMBER 11—Soiree. 'An Expedition in the Himalayas', by J. M. Bechervaise. Exhibits by CSIRO Division of Applied Geomechanics, Department of Fisheries and Wildlife, ICI Australia Ltd., Malacological Society of Australia (Victorian Division), Monash University, Botany Department, and University of Melbourne, Geology Department.

DECEMBER 9—'Expansive Soils', by Dr G. D. Aitchison.

Attendances at Ordinary Meetings of the Society totalled 690.

ANNUAL REPORT

MEMBERSHIP—During the year thirty new Members were admitted to the Society, eighteen resignations were accepted, and two members were removed.

Sir Samuel Wadham was elected a Life Member (*Honoris Causa*). Membership at 29th February, 1972 was: Honorary Life Members, 3; Life Members, 29; Members, 486; Associates, 87. Total, 605.

Council recorded with regret the deaths of Mr K. Byron Moore, Mr E. J. Rowlands and Mr Robin Boyd.

ROBIN GERARD PENLEIGH BOYD, CBE., D.Litt. (Hon.), FRAIA, Hon. FAIA, was born in Melbourne in 1919 and, after war service in the Australian Survey Corps, began his professional career in 1946. He was acutely aware of the community's need for a more critical appreciation of the rapidly growing built environment if the natural beauty of the countryside was to be conserved and not despoiled by indiscriminate industrial and residential development. His ability as professional designer and influential writer was reflected in awards of distinction and other tributes paid locally and overseas.

His wider public duties brought him into close contact with scientists, particularly those engaged in environmental and building research studies relating to human needs. He would, where possible, make the fullest use of natural materials—stone and timber—obtainable near at hand, as exemplified in the Natural History Centre in the Tower Hill Reserve which in construction and design is in the closest harmony with its surroundings. During his association with the Society's Honorary Architect, Sir Roy Grounds, he personally gave to the Society much valuable advice and assistance in his professional field.

CONGRATULATIONS—Council extends its congratulations to Mr J. E. Cummins, OBE, Professor H. C. Forster, OBE, Professor E. S. Hills, CBE, and Mr J. T. Reid, CMG, who were honoured by Her Majesty the Queen during the year.

Council also congratulates Mr A. C. Beaglehole on the award of the Natural History Medallion for 1971.

PROCEEDINGS—During the year the Society published Volume 84, Parts 1 and 2 of *Proceedings* at a cost of \$8,200. Council acknowledges with gratitude grants towards the cost of publication from the Government of Victoria, the National Museum of Victoria, and the Universities of Melbourne and New England.

LIBRARY—2,756 volumes and parts were received during the year, mainly from exchanges with 62 Australasian and 274 overseas organizations. During the year \$229 was contributed by Members towards the cost of binding, and 69 volumes were bound at a cost of \$285. Binding of a further 28 volumes is in hand. 481 items were borrowed from the Library (510 in 1970, 453 in 1969).

HALL—In addition to the Society and the Royal College of Obstetricians and Gynaecologists, 27 professional and other bodies held 85 meetings on the premises compared with 65 in 1970.

FINANCIAL STATEMENT—It should be pointed out that despite ever increasing costs, the Society has been able to take action to hold its financial position. However, expenditure on printing and maintenance is expected to increase substantially. With regard to 'sundry purchases' it should be pointed out that these are largely for equipment of a capital nature.

Council, on behalf of the Society, expresses its thanks to the many persons and organizations who have given valuable assistance during the year: Sir Ian Potter (Hon. Financial Adviser), Mr T. C. Boehme (Hon. Auditor), Mr F. Suendermann, on behalf of Sir Roy Grounds (Hon. Architect), Phillips Fox and Masel (Hon. Solicitors), ICI Australia Ltd., The National Can Company, the Parks and Gardens Department of the Melbourne City Council, and Mr and Mrs A. Sadik.

Thanks are also due to the Executive Officer, Dr R. R. Garran, for his careful and constructive management of the Society's affairs.

This Report has been accepted by Council for submission to the Annual General Meeting on 9th March, 1972.

A. DUNBAVIN BUTCHER,
President

BALANCE SHEET AS AT 31st DECEMBER, 1971

| LIABILITIES | | ASSETS | |
|-------------|-----------------------------|--------------|---|
| 1970 | | \$85,500 | Building |
| \$163,929 | Accumulated Funds at 1/1/71 | \$170,675.45 | Debentures at cost (Face Value \$52,700) |
| 6,746 | Add Surplus of Income | 7,366.91 | Shares (at cost) |
| | | | 10,758 |
| | | | 11,756 |
| | | | Stock of Publications at 31/12/71 |
| | | | 1,140 |
| | | | National Bank of Australasia |
| | | | 664 |
| | | | Office Furniture & Machines—at written down value |
| | | | 769 |
| | | | Subscriptions in Arrears |
| | | | 451 |
| | | | Sundry Debtors |
| | | | 8,000 |
| | | | Loans—Tricontinental Corpn. Ltd. @ 6% on call |
| | | | — |
| | | | Loans—Gollin & Co. |
| | | | 1,188.00 |
| | | | 773.50 |
| | | | 422.96 |
| | | | 8,000.00 |
| | | | 5,000.00 |
| | | | \$178,202.35 |
| | | | \$170,758 |
| | | | \$178,202.35 |

I report that I have conducted an Audit of the Books of Account and Records of the Royal Society of Victoria for the year ended 31st December, 1971, and have prepared the Income and Expenditure Account for that year and a Balance Sheet as at 31st December, 1971.

In my opinion the Statement of Income and Expenditure correctly records the transactions of the Society during the period ended 31st December, 1971 and the Balance Sheet exhibits a true and fair view of the financial position of the Society as at that date. I have also examined the Registers of the Society including that of the members and find them to be in order.

I have received all the information and explanations which from time to time I have required from the Executive Officer (Dr. R. R. Garran) and have accepted his figure for the value of the stock of *Proceedings* on hand at a balance date.

(Signed) T. C. BOEHME, F.C.A.

Honorary Auditor

SCHEDULE OF SECURITIES AND INVESTMENTS AT 31st DECEMBER, 1971

| ORDINARY SHARES | | | | DEBENTURES | | | |
|---|---------|---------------|----------|---------------|---|-----------|-------------|
| | Type | Fully Paid to | No. Held | Probate Value | | Int. Rate | Face Value |
| Australian Foundation Investment Co. Ltd. | Ord. | 50c | 1,000 | 1,160 | Australian Guarantee Corp. Ltd. | 8% | \$100 |
| Australian Foundation Investment Co. Ltd. | Ord. | 50c | 100 | Bonus Issue | Australian Newsprint Mills Holdings Finance Corporation of Australia Ltd. | 7½% | 200 |
| Australian & Kandos Cement Holdings Ltd. | Ord. | 50c | 1,000 | 1,220 | Esso Standard Oil (Aust.) Ltd. | 8% | 3,300 |
| Dunlop Australia Ltd. | Ord. | \$1 | 1,000 | 1,850 | Commonwealth Industrial Gases Ltd. Repco. Ltd. | 7½% | 4,000 |
| Dunlop Australia Ltd. (new issue at cost) | Ord. | \$1 | 142 | 142 | Australian Paper Manufacturers Ltd. Containers Ltd. | 7½% | 10,000 |
| Email Ltd. | Ord. | 50c | 500 | 355 | Carlton & United Breweries Ltd. Blue Metal Industries Ltd. | 8½% | 1,500 |
| Elder Smith Goldsbrough Mort Ltd. | Ord. | \$2 | 824 | 1,730 | Mercantile Credits | 9% | 8,000 |
| National Bank of Australasia Ltd. | Ord. | \$1 | 1,250 | 3,787 | John Lysaght (Aust.) Ltd. Myer Emporium | 9% | 400 |
| Dunlop Australia Ltd. | Ord. | 50c | 228 | 228 | Mercantile Credits | 8% | 8,000 |
| | | | | | | 9% | 2,000 |
| | | | | | | | 200 |
| | | | | | | | 47,700 |
| PREFERENCE SHARES | | | | | UNSECURED NOTES | | |
| Associated Dairies Ltd. | 7% Cum. | Pref. | 200 | \$10,472 | General Motors Acceptance Corpn. | 7½% | 4,700 |
| As per Balance Sheet | | | | 400 | General Motors Acceptance Corpn. | 8½% | 300 |
| | | | | \$10,872 | | | \$52,700 |
| | | | | | DEBENTURES—Per Balance Sheet at Cost | | |
| | | | | | | | \$52,219.90 |

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